STDES-CBMLoRaBLE test report

Introduction

The STDES-CBMLoRaBLE is a development solution that facilitates the prototyping, testing, and evaluation of industrial nodes with multiconnectivity and several sensors for condition and structural health monitoring.

The solution comes with comprehensive firmware libraries and different modules, to provide an easy approach to build an industrial IoT node.

The hardware is designed as a modular platform, assembled from the following four boards:

- the system on board (SB), which hosts long and short-range connectivity as well as security functionalities and embedded power management circuitry;
- a main board to host the SB module soldered, additional power management sources and security, external memory, expansion connectors, and additional connectors for programming;
- two expansion boards that host all the sensors. You can place the expansions close to different equipment, if needed, and minimize the size and weight of the sensing elements.

The released package includes an application firmware, which performs the signal processing for vibration analysis and the inclination algorithm. By running the application example, signals from sensors are acquired, processed, and sent to user interfaces for monitoring/diagnostic purposes. Measured and/or processed data are sent dynamically, according to the status determined by the running algorithm.

The platform is compliant with the STBLESensor app and the DSH-PREDMNT AWS dashboard. It can be connected to one or both user interfaces for settings and monitoring purposes.

Power management is optimized to extend the battery life and allow choosing among three power supply options (battery, USB, and industrial bus (12-48 V)).

Figure 1. STDES-CBMLoRaBLE reference design

Fully assembled board developed for performance evaluation only, not available for sale

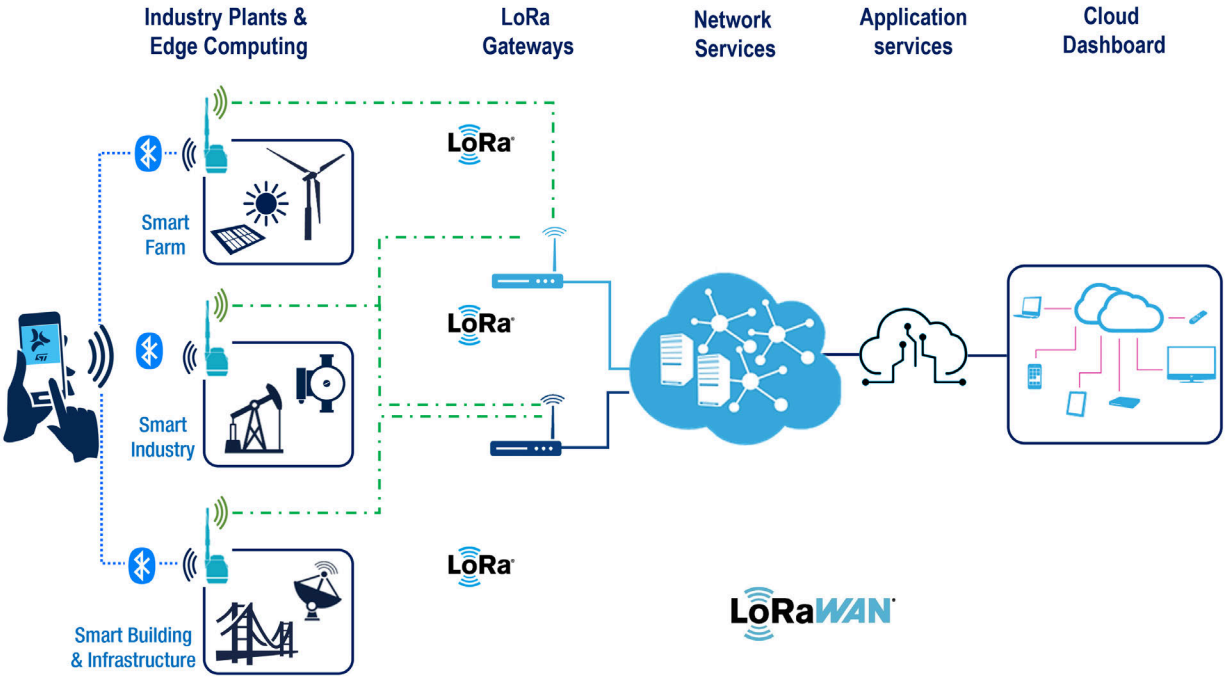
1 Overview

The STDES-CBMLoRaBLE platform implements an IIoT node able to collect all the measurements for condition based monitoring (CBM) and structural health monitoring (SHM), sending these results and the environmental data, using a short range Bluetooth® Low Energy connectivity, or a long range remote connectivity managed by the LoRa protocol.

The LoRa gateways extend the connectivity through a LoRaWAN® network architecture that forwards the packets to the network server, handling transmission, filtering redundant received packets, and scheduling acknowledgments.

The application server decodes and assembles all the packets transmitted to publish on the cloud dashboard, all the data processed by the end node, including events and machinery status, enabling the remote equipment monitoring. The solution can be affordable in industrial fields that operate in remote areas, with harsh environmental conditions and low connection capability.

Figure 2. STDES-CBMLoRaBLE application overview



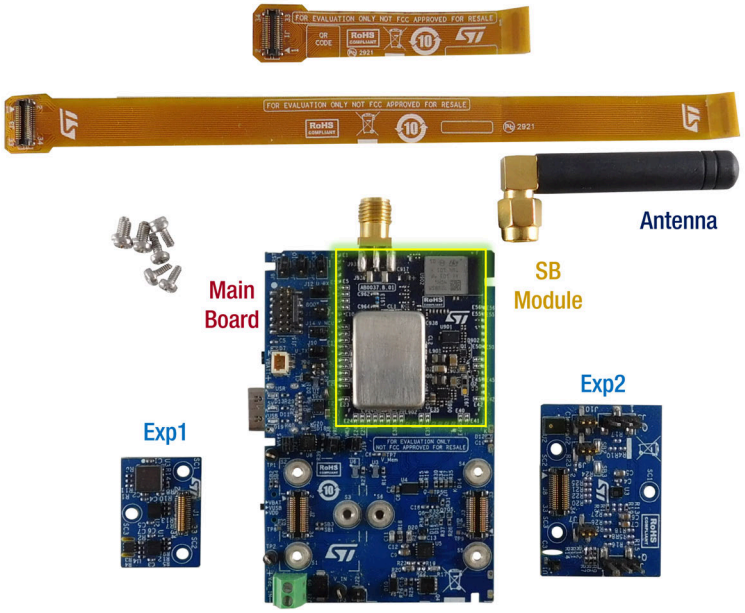
1.1 Hardware description

As described before, the STDES-CBMLoRaBLE is a modular system that consists of several components including the following four boards:

- a solderable system on board (SB) including the following ICs::
  - STM32WB5MMG 2.4 GHz wireless dual core SoC module as the main application processor, which supports Bluetooth® Low Energy 5.0
  - STM32WL55JC sub 1-GHz wireless dual core SoC, which supports multimodulation (LoRa and GFSK)
  - ST1PS02CQTR up to 400 mA nano-quiescent synchronous step-down converter with digital voltage selection, Power Good, and AUX switch
  - STSAFA110DFSPL02: secure element IC that provides authentication and secure data management services

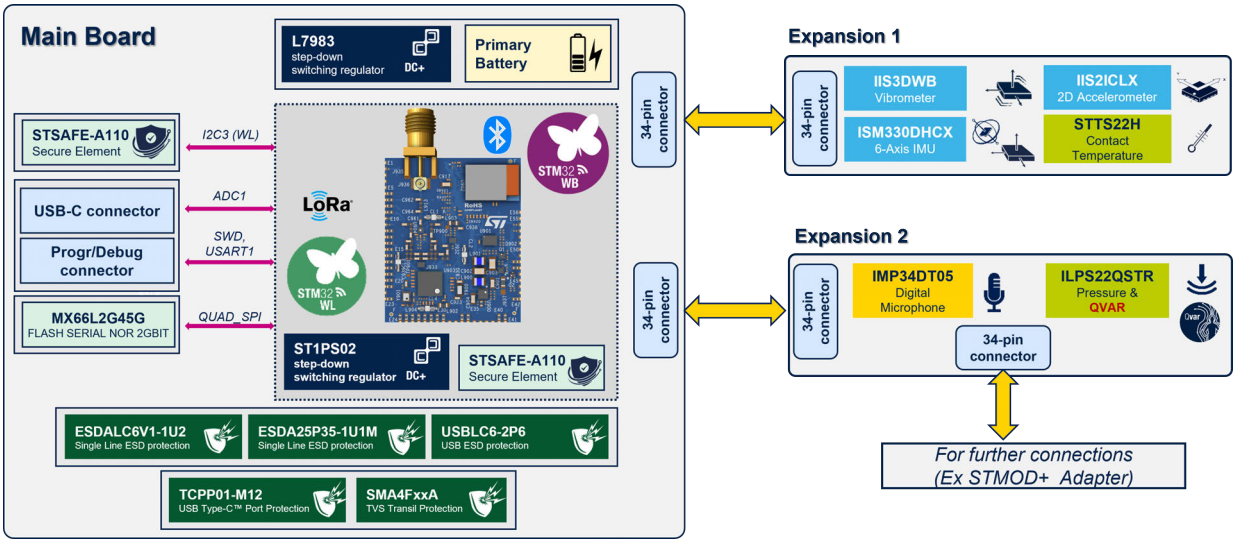
- a main board with the system on board soldered, plus the following ICs:
  - L7983PUR: 60 V, 300 mA synchronous step-down switching regulator with 10 µA quiescent current
  - TCPP01-M12: IC USB Type-C® port protection
  - MX66L2G45GXRI00: 2G bit Serial NOR Flash Memory
  - STG4160: analog switch ICs LV 0.5 ohm SPDT 15 kV 1.65 to 4.8 V 0.2 µA
- expansion board no. 1 that hosts the following key components:
  - ISM330DHCX: iNEMO inertial module with machine learning core and finite state machine with digital output for industrial applications
  - IIS3DWB: ultra-wide bandwidth, low-noise, 3-axis digital vibration sensor
  - IIS2ICLX: high-accuracy, high-resolution, low-power, 2-axis digital inclinometer with embedded machine learning core
  - STTS22H: low-voltage, ultra-low-power, 0.5°C accuracy I²C/SMBus 3.0 temperature sensor
- expansion board no. 2 hosts the following key components:
  - IMP34DT05: MEMS audio sensor omnidirectional digital microphone for industrial applications
  - ILPS22QS: dual full-scale, 1260 hPa and 4060 hPa, absolute digital output barometer with embedded Qvar electrostatic sensor
- short and long flexible PCBs: to connect remotely the two expansion boards to the main board. This feature is useful when you want to place the two different kinds of sensors on two different parts of the same equipment

Figure 3. STDES-CBMLoRaBLE components



The system supports both short- and long-range connectivity, Bluetooth® Low Energy and LoRa, which can be used independently, plus an additional serial connectivity, based on the UART virtual COM, for debugging and testing purposes, addressable by the programming connector.

Figure 4. **STDES-CBMLoRaBLE block diagram**



1.2 Assembly scenarios

Thanks to two embedded 34-pin expansion connectors, external modules, and the flexible PCBs, the STDES-CBMLoRaBLE platform has been assembled and tested in three different ways as detailed below:

- Scenario 1
  - Expansion board 1 stacked on the main board, bottom exposed, screwed/not screwed
  - Expansion board 2 stacked on the main board, screwed/not screwed

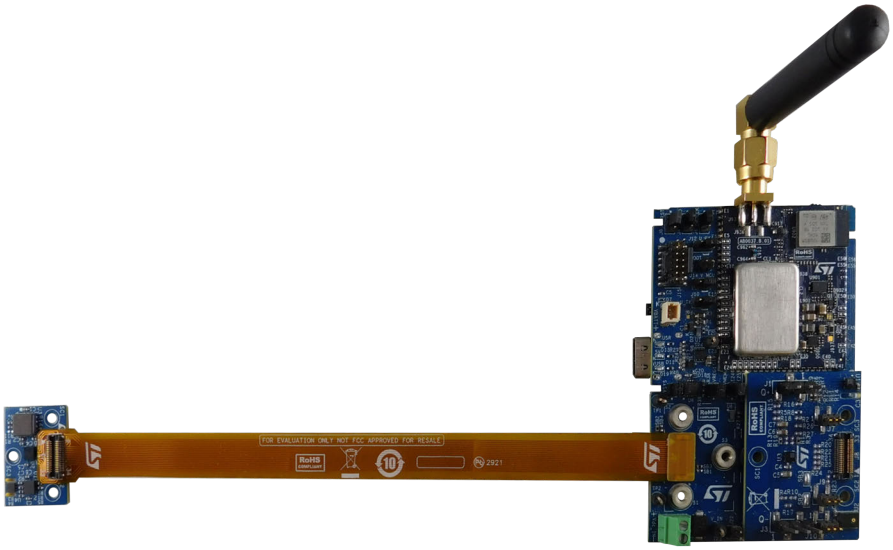
Figure 5. **Scenario 1**

- Scenario 2
  - Expansion board 1 screwed on the main board, with the top exposed, through the short flexible PCB
  - Expansion board 2 stacked on the main board, screwed/not screwed

Figure 6. Scenario 2

- Scenario 3
  - Expansion board 1 displaced through the long flexible PBC
  - Expansion board 2 stacked above the main board, screwed/not screwed

Figure 7. Scenario 3



Other possible scenarios should be built using different combinations of the previous ones, respecting the pins numbering when connecting the 34-pin header and the socket.

2 Specifications

2.1 Power supply

The system allows choosing among three different power supply options:

- Industrial bus: 12 V ÷ 48 V
  - SW3 in VDD position
  - Used power supply: E3634A by Agilent
- USB Type-C®: 5 V
  - SW3 in VUSB position
  - USB Type-C® cable connected to CN1
- Primary battery: 3.6 V ÷ 4.5 V
  - SW3 in VBAT position
  - Battery: any standard AA battery (1.5 V), packaged in a “series” battery holder, to supply up to 3 x 1.5 V = 4.5 V

2.2 Jumpers and switches

Figure 8. On-board jumpers and switches: top and bottom views

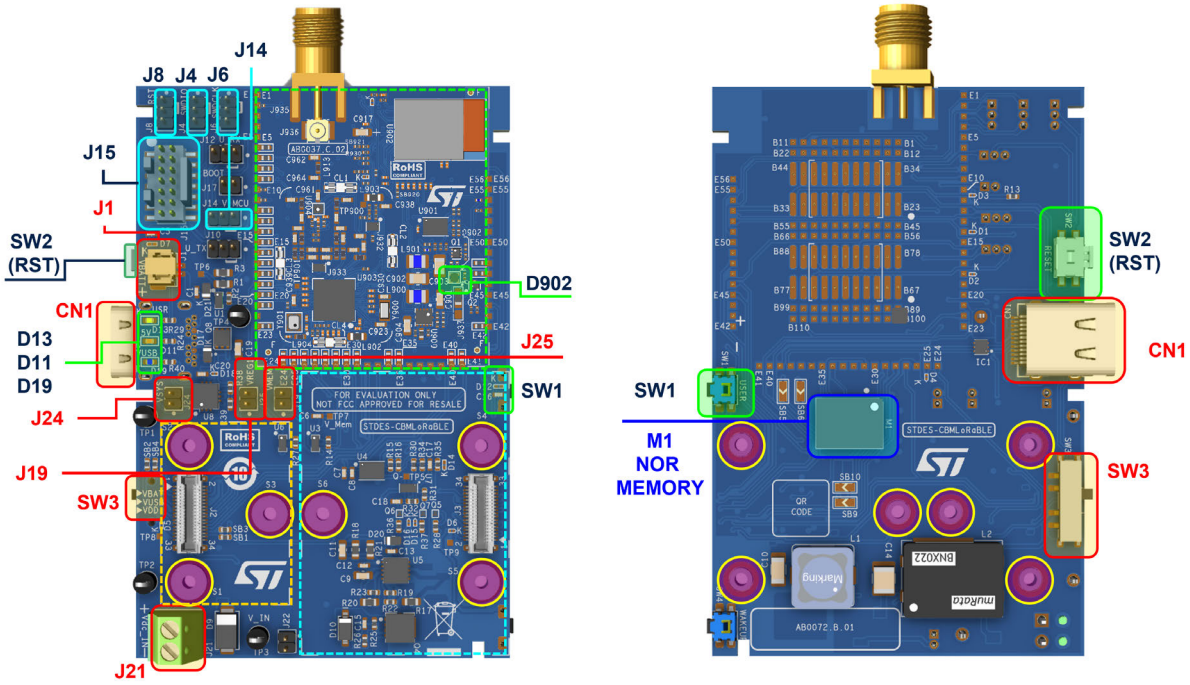


Table 1. Main configuration jumpers

Name	Function	Domain
J1	Battery plug	Power domain
J4, J6, J8, J14	Jumper to select the processor for programming (positions 1-2 for STM32WB, positions 2-3 for STM32WL)	Programming
J19	Jumper to supply VReg1 to the expansion board	Power domain
J21	Industrial bus connector	Power domain
J24	Jumper to supply the external voltage to the system	Power domain

Name	Function	Domain
J25	Jumper to supply the external NOR flash memory	Power domain
J15	One four-pin receptacle for SWD/ST-LINK	Programming
CN1	USB Type-C® plug	Power domain

Table 2. Switches and LEDs

Name	Function	Domain
SW1	User button	-
SW2	RST button	-
SW3	Three-pole switch for power source selection (VBATT – VUSB – VIND)	Power domain
D11	VIND LED (to detect the bus)	-
D13	User LED	-
D19	USB LED (for fault detection)	-
D902	RGB LED	-

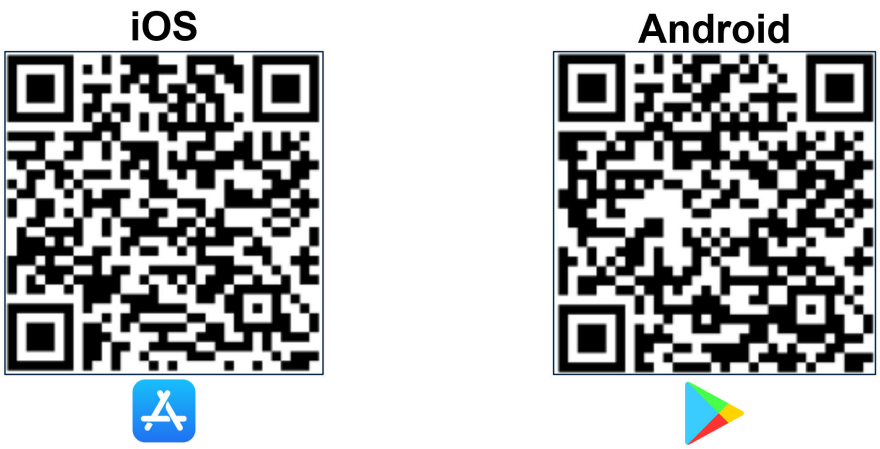
2.3 Software prerequisites and interfaces

The system supports both short- and long-range connectivity, Bluetooth® Low Energy and LoRa, that can be used independently, plus an additional connectivity for device registration and debugging purposes.

The STDES-CBMLoRaBLE is compatible with the STBLESensor app for short-range connectivity and DSH-PREDMNT AWS dashboard for long-range connectivity. In the normal running mode, you can use these two interfaces independently (both connectivity and functionality are present at same time), without the need of choosing one. Under some circumstances, some kind of data on the STBLESensor might pause the long-range transmission, which is retrieved once the data are no more shown on the app.

The STBLESensor app is available for Android and iOS, to handle the data exported by a Bluetooth® Low Energy device using the BlueST protocol, to run the application and the firmware update over-the-air (FUOTA).

Figure 9. QR codes for STBLESensor



The STDES-CBMLoRaBLE is compatible with:

- ST BLE Sensor Android application v4.16.2 (or higher)
- ST BLE Sensor iOS application v4.16.2 (or higher)
- DSH-PREDMNT ST Cloud based web application for condition monitoring and predictive maintenance

- A Windows™ (v7 or higher) PC, with TeraTerm or another terminal emulator software.
  For the third connectivity, the PC terminal console can be used for the device registration phase or in the normal running mode, for an expert user, independently of the other two main connectivities.
- STM32CubeProgrammer software on PC
- Development toolchain and compiler on PC. Considering that the STM32Cube expansion software is designed to support the following environments:
  – IAR Embedded Workbench for ARM® toolchain, release 8.50.9
  – STM32CubeIDE ST Integrated Development Environment for STM32, release 1.9.0

2.4 Programming mode

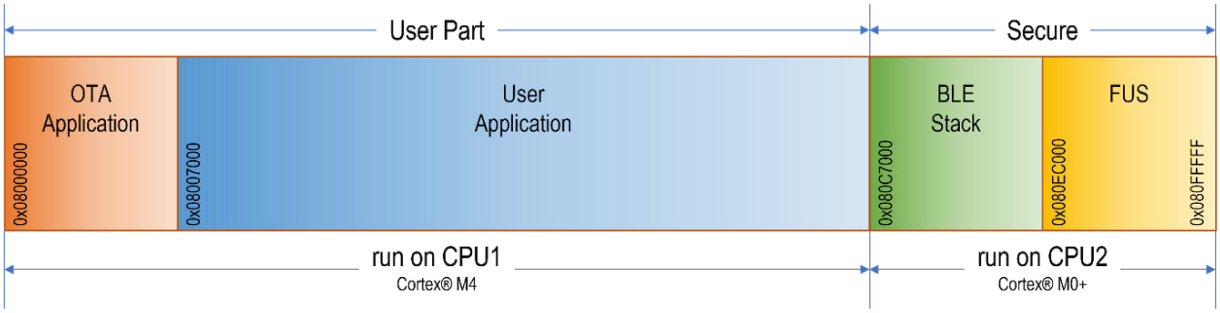
The STM32WB5MMG comes with 1 Mbyte flash memory, shared between the two Arm® cores as user part to be run into the CPU1, Cortex® M4, and secure part to be run into the CPU2, Cortex® M0+. The user part starts from the beginning of the flash memory, whereas the secure part is placed at the end.

A specific memory mapping helps to develop an application easy to update.

To integrate the FUOTA features, the firmware package must be designed as follows:

- the bootloader, in the first main memory address (***0x08000000***), must be an OTA application designed to handle the firmware update procedure
- the user application, in the specific memory address (***0x08007000***), can be updated with the FUOTA and contains the main application
- the secure sectors include the application running in the CPU2 core; the secure part (FUS) is placed at the end and its size depends on the wireless Bluetooth® Low Energy stack to be used (***0x080EC000***)
- you can also update the Bluetooth® Low Energy stack using the same FUOTA functionality, placed at the related fixed address (***0x080C7000***).

Figure 10. STM32WB5MMG memory map for Bluetooth® Low Energy OTA applications



For further details on this topic, please read the AN5247 that describes the procedure for over-the-air (OTA) firmware update on ST32WB devices with Bluetooth® Low Energy (BLE) connection.

In the application firmware, the STM32WB5MMG plays the main role of application processor, providing its main peripherals for application purposes and acts as AT master towards the STM32WL55JC.

The STM32WL55JC is a dual core Arm® Cortex®-M4/M0+ that supports Sub-GHz connectivity, such as LoRa, GFSK, and others. By default, the STM32WL55JC plays the role of network processor running the LoRaWAN modem AT slave firmware, and it is connected to the STM32WB5MMG through the LPUART interface, together with wake-up, reset, and interrupt signals.

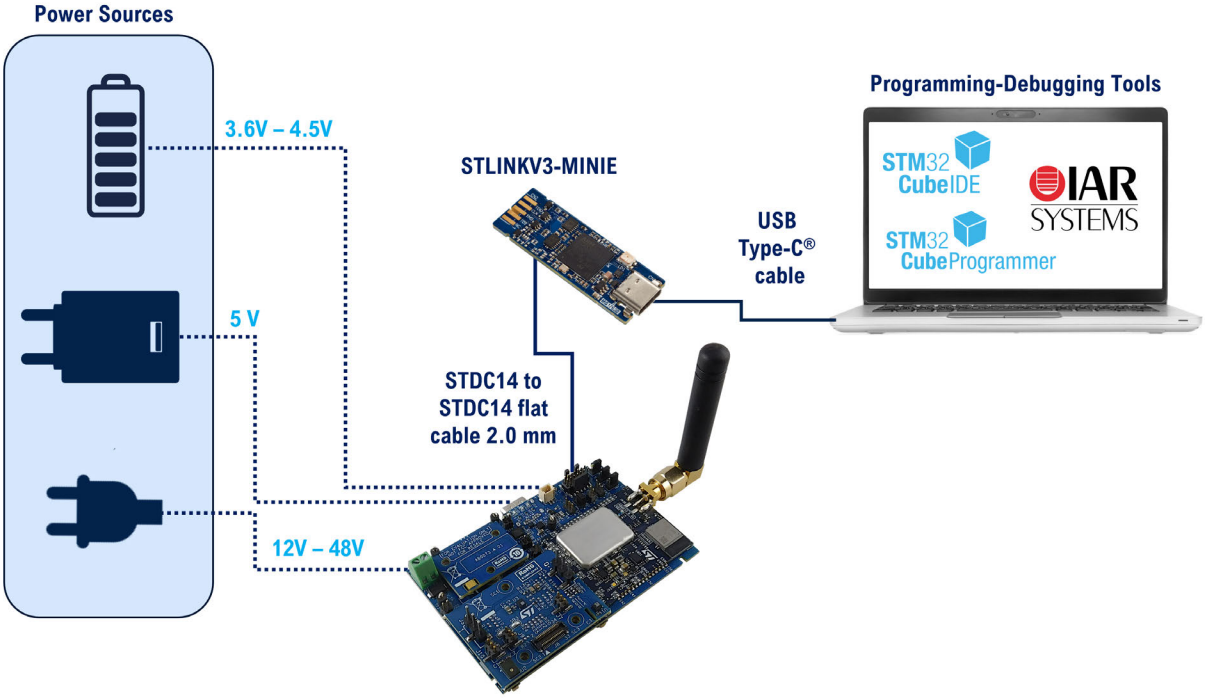
The system has been tested with the firmware codes provided in the package (*STDES-CBMLoRaBLE / ST32WB&STM32WL Binary Update*):

- **STM32WL_LoRaWAN_AT_Slave.hex**: firmware code to program the STM32WL
- **stm32wb5x_FUS_fw_for_fus_0_5_3.bin**: firmware code to program the STM32WB FUS
- **stm32wb5x_BLE_Stack_full_fw.bin**: firmware code to program the STM32WB stack
- **CBMLoRaBLE_FUOTA.hex**: bootloader with FUOTA firmware running on the STM32WB

The application firmware (*CBM_LoRa_IAR.hex*) running on the STM32WB is available in the project folder.

The hardware in-circuit debugger and programmer for STM32 used is the STLINK-V3MINIE.

Figure 11. **Programming/debugging connections**



3 Test setup

3.1 Test conditions and equipment

3.1.1 Connection scenarios

Tests have been performed using all the stacked and displaced boards connection.

3.1.2 Power supply

All the three power supply options were tested as detailed:

- Industrial bus in the range: 12 V ÷ 48 V
  - SW3 in VDD position
  - Used power supply: E3634A by Agilent
- USB Type-C®: 5 V
  - SW3 in VUSB position
  - USB Type-C® cable connected to CN1 and to a laptop
- Primary battery: 3.6 V ÷ 4.5 V
  - SW3 in VBAT position
  - Battery in the range: 3.6V ÷ 4.5 V

3.1.3 Interfaces

Tests were performed using both interfaces (short- and long-range), or one interface only.

If the hardware is properly connected through the STLINK-V3MINIE and the STDC14 cable, the serial connection on the virtual COM port is also available and accessible through a PC terminal console.

3.1.4 Equipment

- Hardware
  - 1 main board
  - 1 expansion #1 board
  - 1 expansion #2 board
  - 2 flexible PCBs (not used in the stacked boards configuration)
  - 1 antenna
- Hardware used for power supply
  - Battery: 3.6-4.5 V
  - USB Type-C® cable
  - Bench power supply: E3634A by Agilent
- Hardware for programming
  - STLINK-V3MINIE
  - 14-pin SWD cable
  - USB Type-C® cable
- Hardware for application testing
  - A PC or laptop
  - A mobile phone or notepad
  - LoRa TTN gateway; we used the following ones:
    - The Things Industries Indoor Gateway, 868 MHz
    - LoRa/LoRaWAN Gateway – 868 MHz with Raspberry Pi 3

- Software
  - STM32 programming IDE for programming/developing; testing were done with:
    - IAR Embedded Workbench IDE – ARM 8.50.9
    - STM32CubeIDE 1.9.0
  - STBLESensor app (for short range connectivity)
  - Account on TTN network server + DSH-PREDMNT (for long range connectivity)

3.2 Procedure

Once you have programmed the microcontroller with the firmware codes as above mentioned, check that every component is working properly.

Step 1. Verify the Bluetooth® Low Energy connection through the serial interface.
The amber LED should blink on the board when using the STBLESensor app.

Step 2. Check the Bluetooth® Low Energy functionality by swapping among all windows, cross-checking data, and updating options.

Step 3. Verify the LoRa Join through the serial interface (for example, Teraterm), on the TTN network server.
The green LED blinks when the connection to the LoRa network is established.

Step 4. Check the LoRa data transmission by reading sensors data through the serial interface, on the TTN network server (raw data) and on the dashboard.

Step 5. Verify the LoRa fragmented data by reading the raw data on the TTN network server and the dashboard.
Through the debugger, missing frames are forced to verify the correct recovery.
Among data for vibration analysis, FFT data are transmitted.

Note: FFT and accelerometer data transmission through the STBLESensor temporarily interrupt the transmission to the dashboard.

Step 6. Verify the sensor data through one of the three available interfaces.

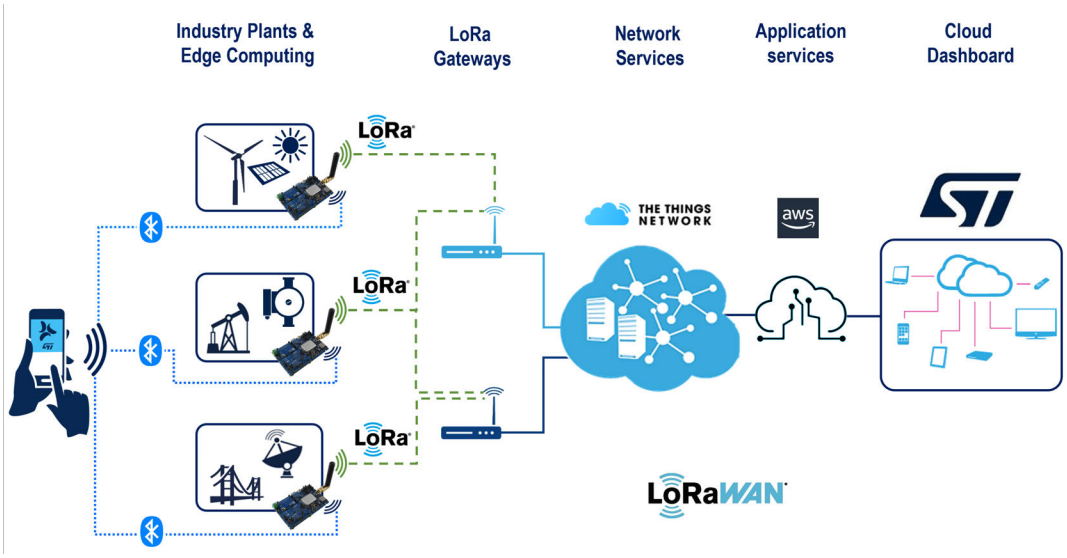
4 Measurements/test data

As described in Section 1 Overview, the STDES-CBMLoRaBLE features several functionalities of a typical IIoT end-node with short- and long- range connectivity, supported by two different HMI interfaces for nearby (BLE) or remote (LoRa) control (both are very suitable for equipment condition and structural health monitoring).

To test the platform, the application functionality shown in Figure 2. STDES-CBMLoRaBLE application overview has been completed and supported through the following three main basic services in the LoRaWAN architecture:

- the TTNv3 network server for packet forwarding and downlink message handling
- an AWS adapter for packet decoding, control for lost frames recovery in downlink and bridging (from HTTP to MQTT protocols) towards the dashboard
- the predictive maintenance dashboard (DSH-PREDMNT) to expose the data incoming from the embedded processing, highlight specific diagnostic events, and store historical data.

Figure 12. STDES-CBMLoRaBLE: complete application workflow



4.1 STBLESensor application results

When the STDES-CBMLoRaBLE has been successfully programmed, powered, and switched on, it acts as an IIoT BLE peripheral device and sends advertising packets to establish a connection with a BLE central device. At the same time, a connection to the LoRaWAN network is established to provide the same measurement to the application dashboard.

Launching the STBLESensor app, you can test the application connecting a device and viewing measurements.

Figure 13. **STBLESensor app: connection start and environmental test**

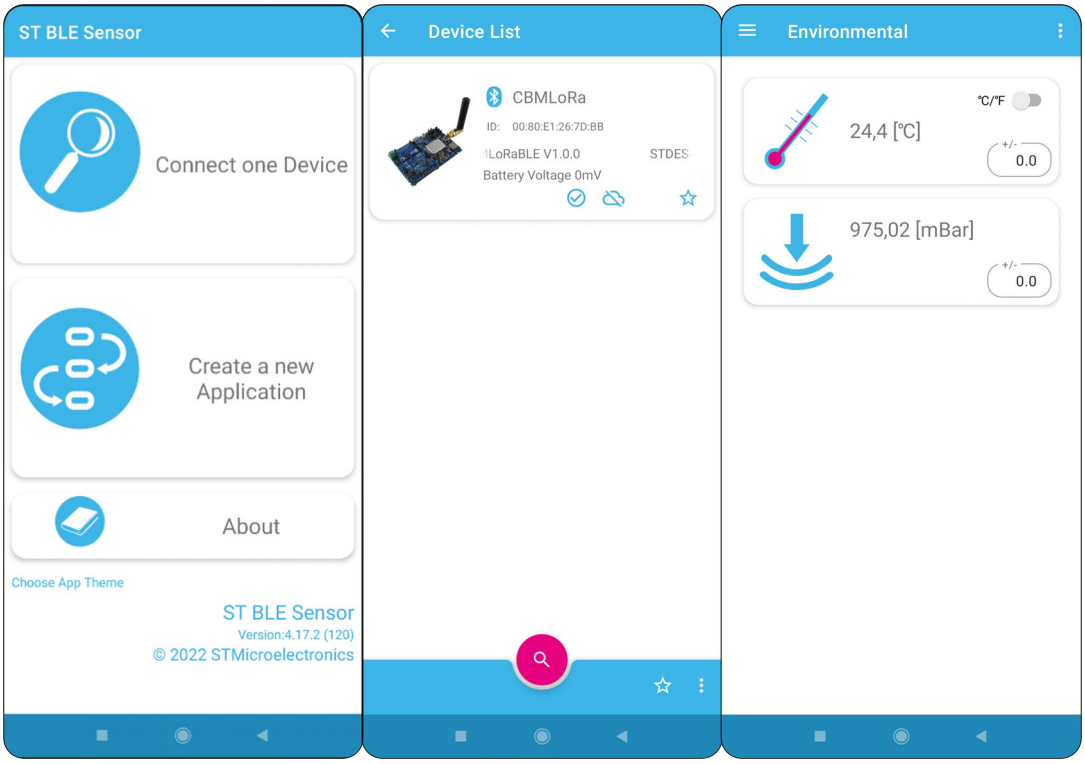


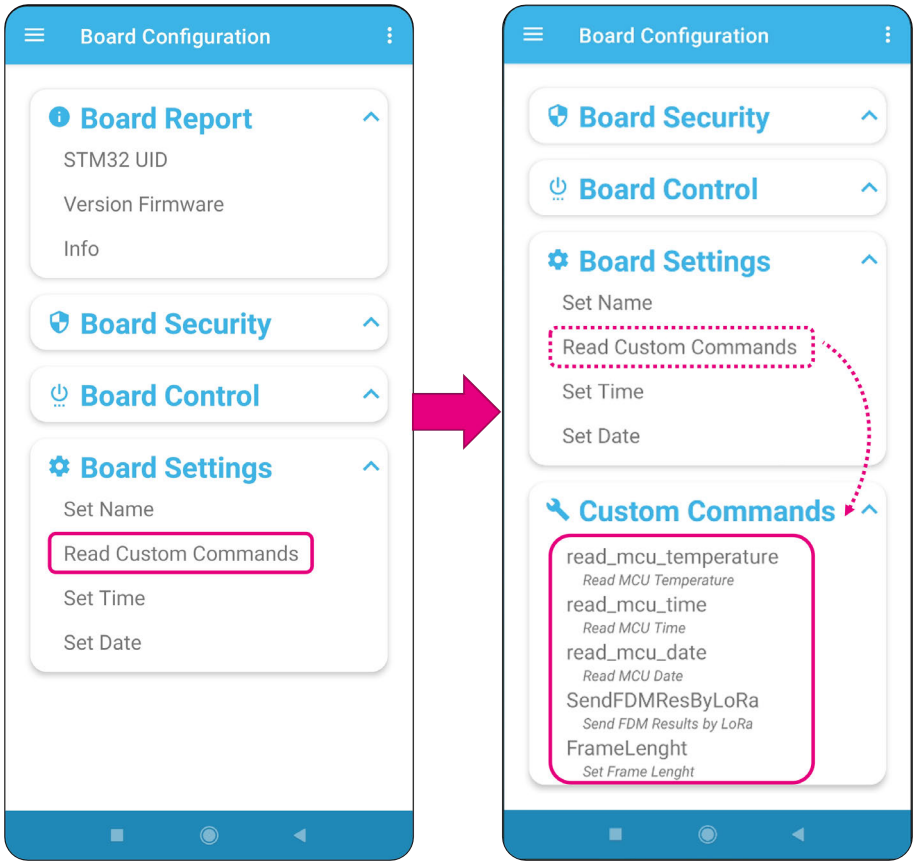
Figure 14. **STBLESensor app: FFT, accelerometer data, and PdM measurements**

The application firmware released handles all the data for PdM and the orientation algorithm processing.

All these data are cyclically sent through LoRa to the LoRaWAN network into the dashboard and through BLE to the STBLESensor App on demand (according to the active window).

By using window *Board Configuration→ Board Settings → Read Custom Commands*, you can read, modify parameters, and force data transmission through the LoRa connectivity.

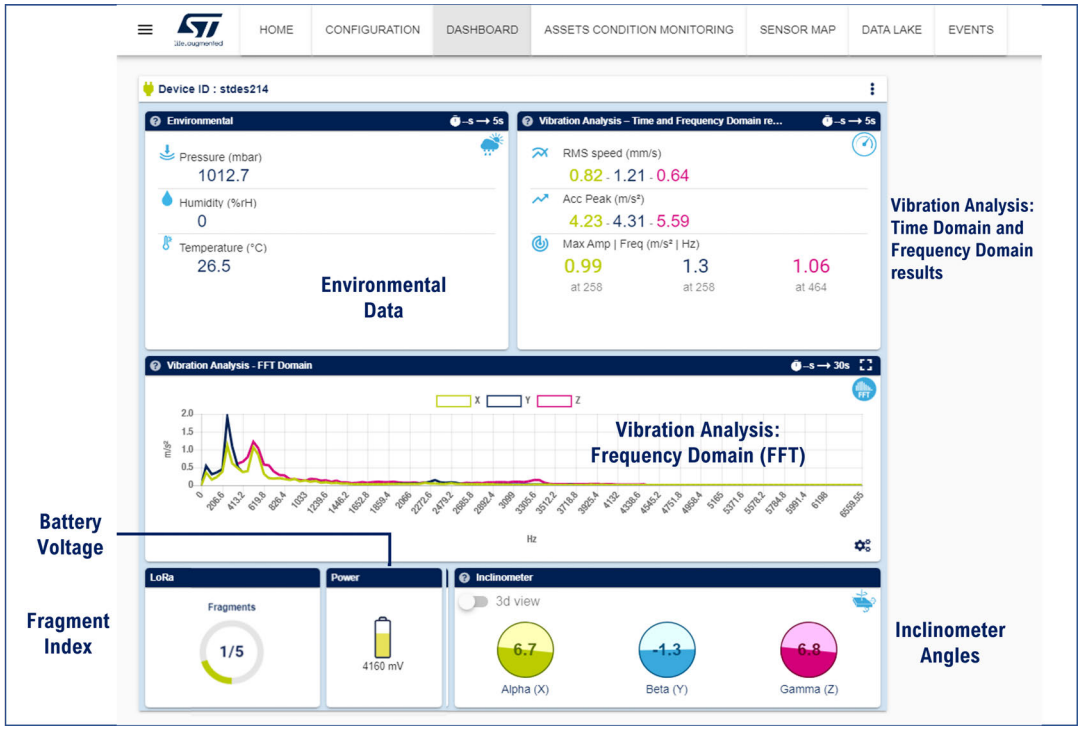
Figure 15. STBLESensor app: custom commands



4.2 DSH-PREDMNT application results

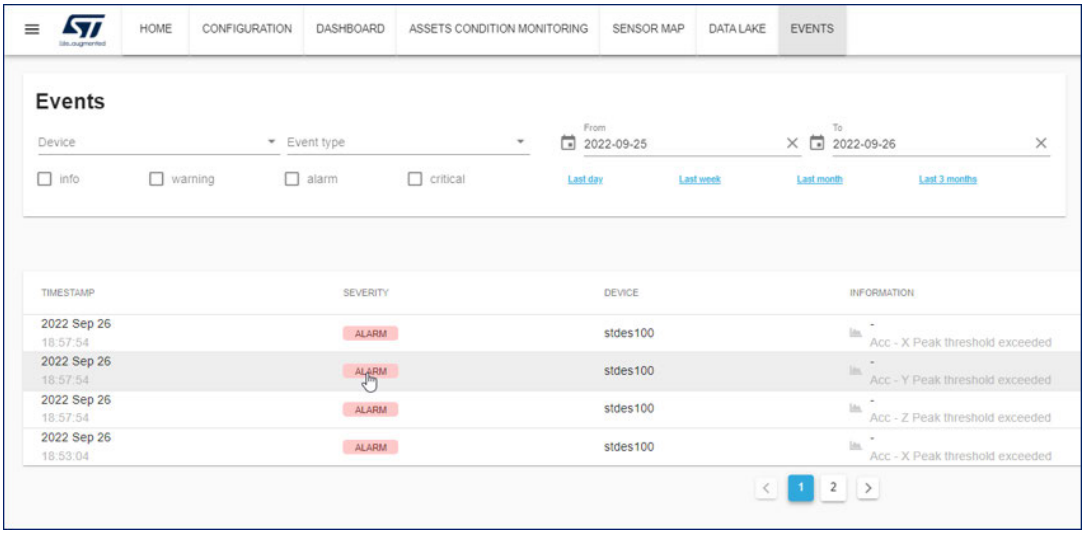
Using the DSH-PREDMNT AWS dashboard, it is possible to verify all the measurements inside a single page, already available in the BLE interface, plus the angles outgoing from the End-Node algorithm with inclinometer data.

Figure 16. **DSH-PREDMNT AWS dashboard: device page**



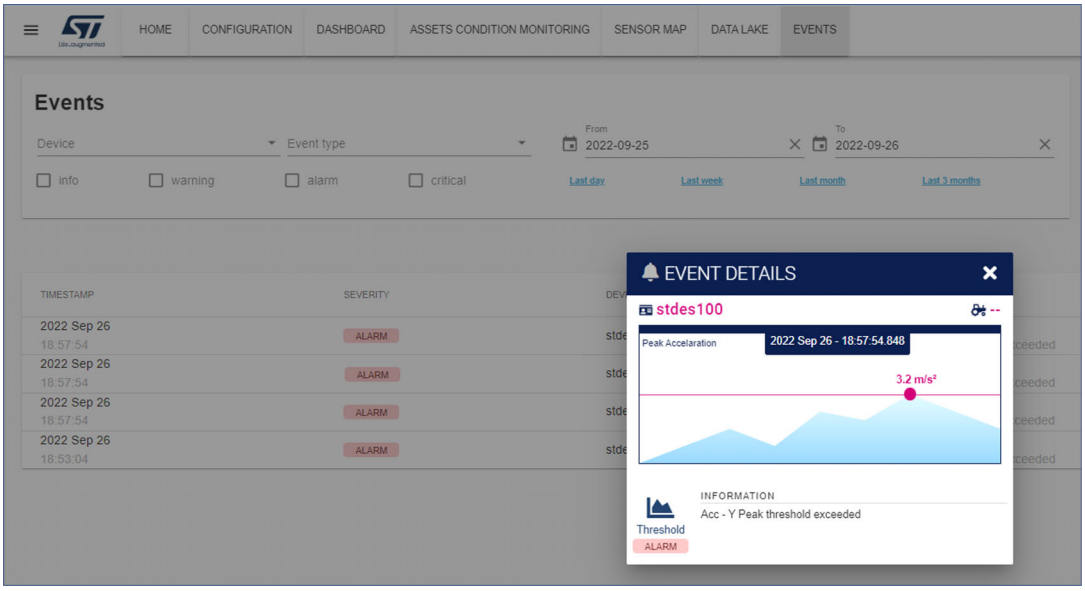
A further capability is provided with a specific page dedicated to the PdM events, where all the historical warning or alarm status are available, related to the embedded diagnostic comparison for time and frequency domain values.

Figure 17. **DSH-PREDMNT AWS dashboard: events page**



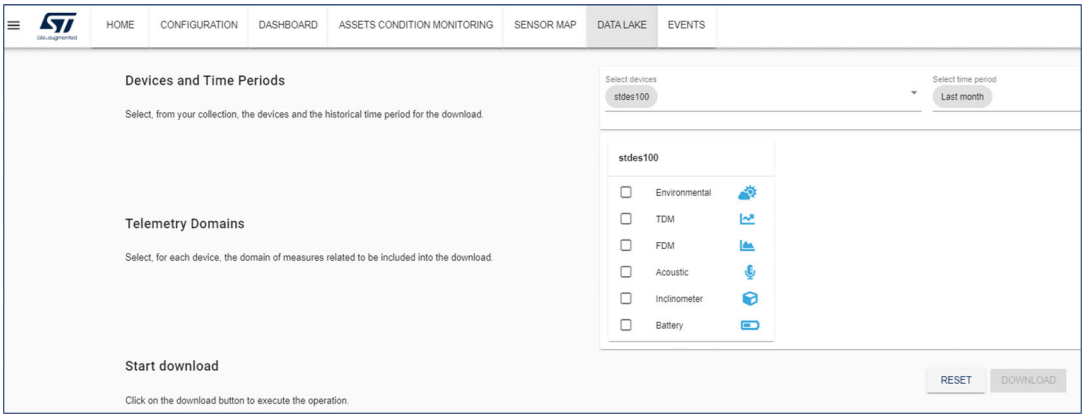
For each event stored in the list, it is possible to get more information about the related measurement, which exceed the configured threshold, and timing details.

Figure 18. **DSH-PREDMNT AWS dashboard: single event details**



In the *DATALAKE* page, it is possible to retrieve all the data provided from the IIoT node, shown in the dashboard, selecting the timing interval and the desired measurements.

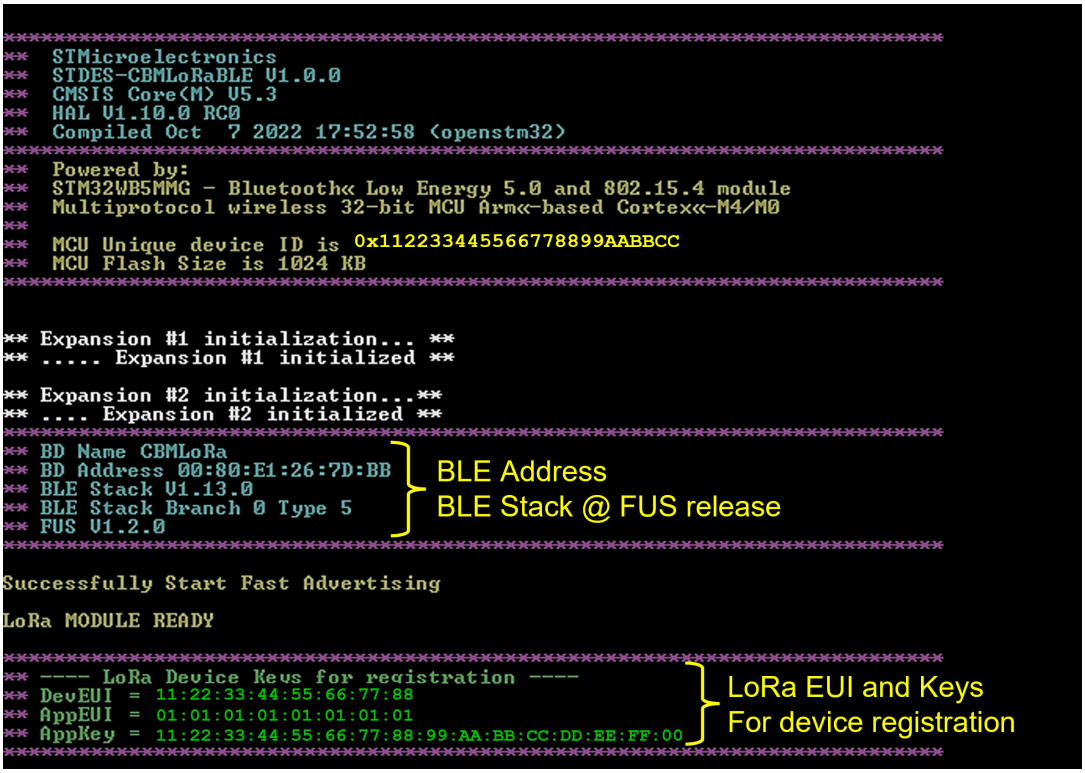
Figure 19. **DSH-PREDMNT AWS dashboard: DATALAKE storage**



4.3 PC serial terminal application results

Using the connectivity described in Figure 11. Programming/debugging connections and a PC standard serial terminal console, it is possible to control the application execution, getting also information about drivers and the library included in the firmware, identification address for BLE, and all EUIs and KEYS for LoRa provisioning.

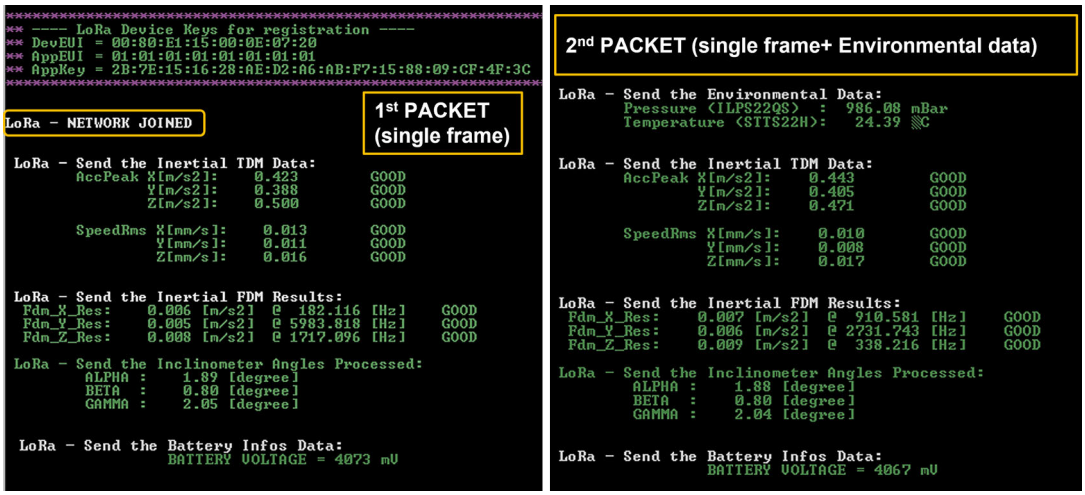
Figure 20. **Terminal console: application start**



When the application starts, the BLE services remain in advertising mode until the BLE mobile requests a connection, and the LoRa services remain in the idle state until the connection is established in the network server by the gateway.

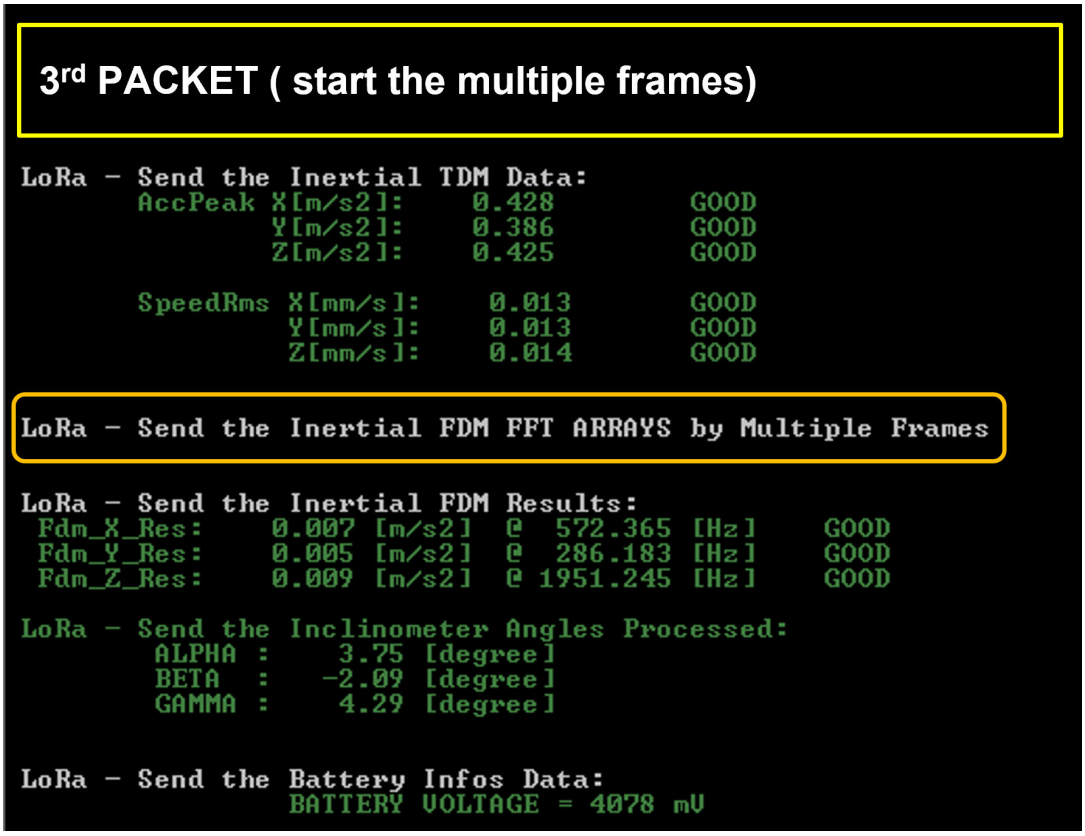
When the LoRa connectivity is joined, the STDES-CBMLoRaBLE is ready to send all the measurements using several single frames, which include or not the environmental data.

Figure 21. **LoRa packets: two single frame types**



When a configured time slot is elapsed, or in case of a user specific request, the application starts with a multiple frame transmission to send the FFT arrays to the dashboard.

Figure 22. LoRa packets: starting with multiple frames



5 Schematic diagrams

Figure 23. **STDES-CBMLoRaBLE schematic diagram (1 of 10) – Main board/Top view**

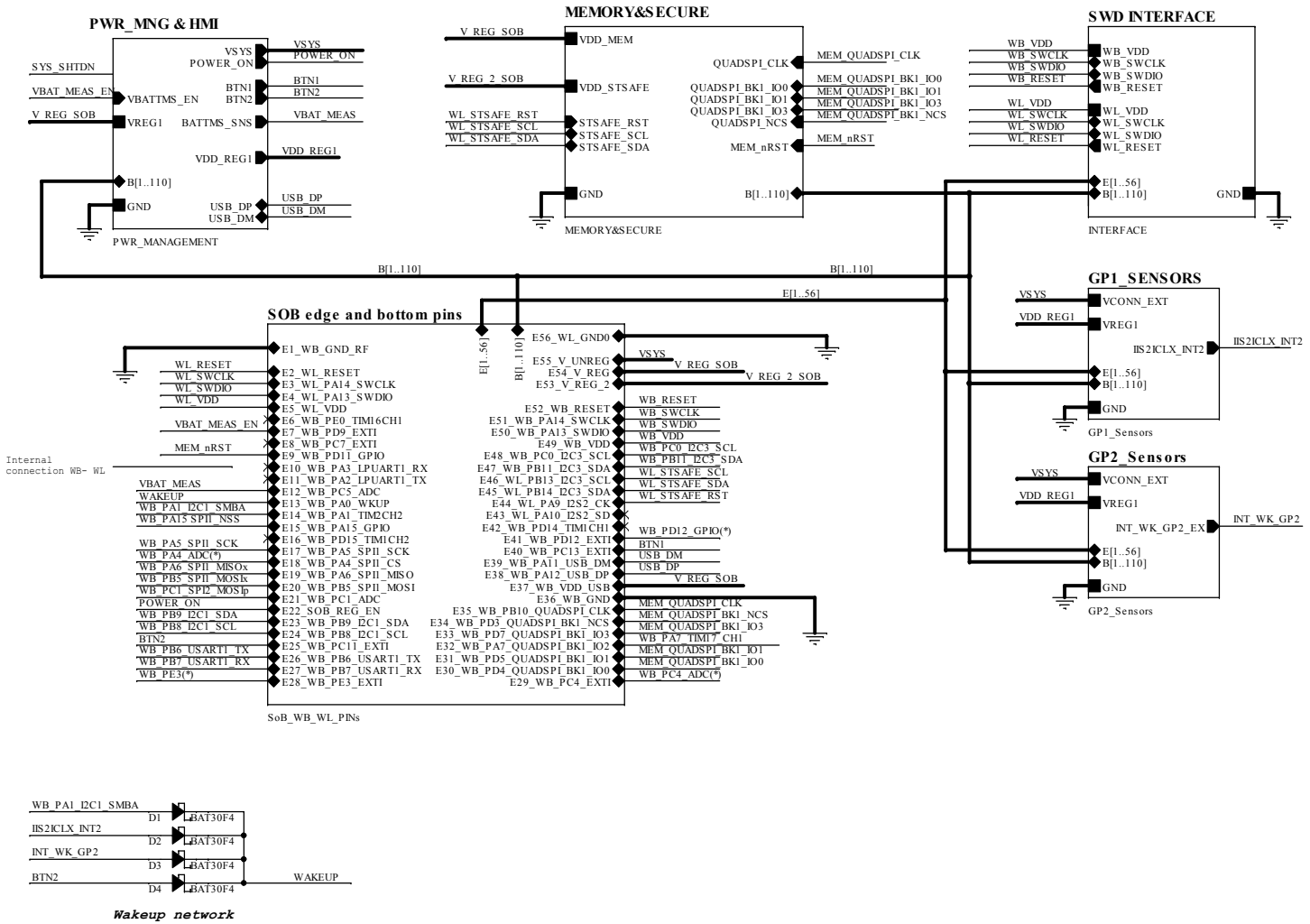
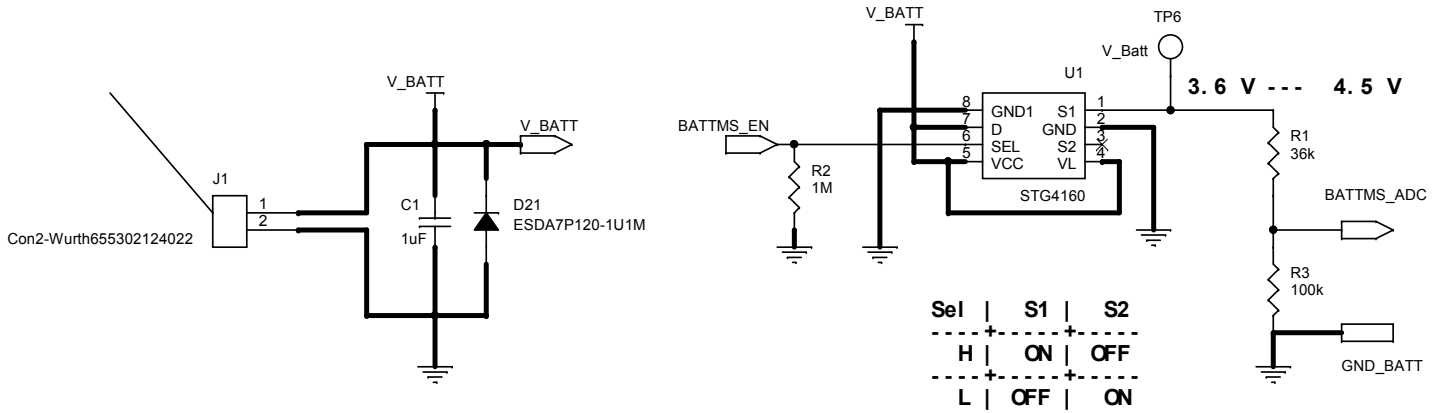


Figure 24. **STDES-CBMLoRaBLE schematic diagram (2 of 10) – Main board/Battery**



Voltage addressed:
Min -> 3.6 V
Max -> 4.5 V

Figure 25. STDES-CBMLoRaBLE schematic diagram (3 of 10) – Main board/GP1_Sensors

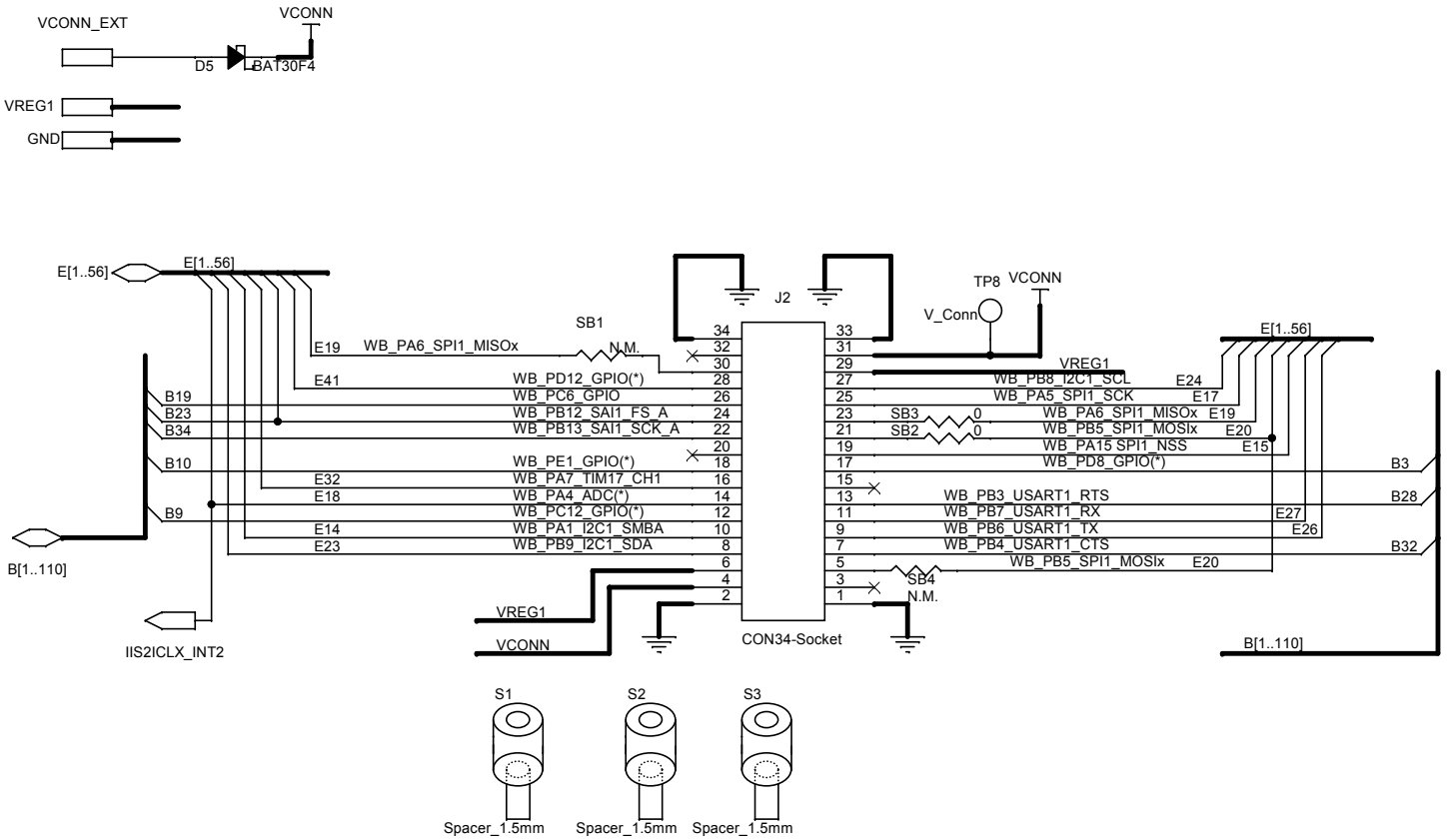


Figure 26. STDES-CBMLoRaBLE schematic diagram (4 of 10) – Main board/GP2_Sensors

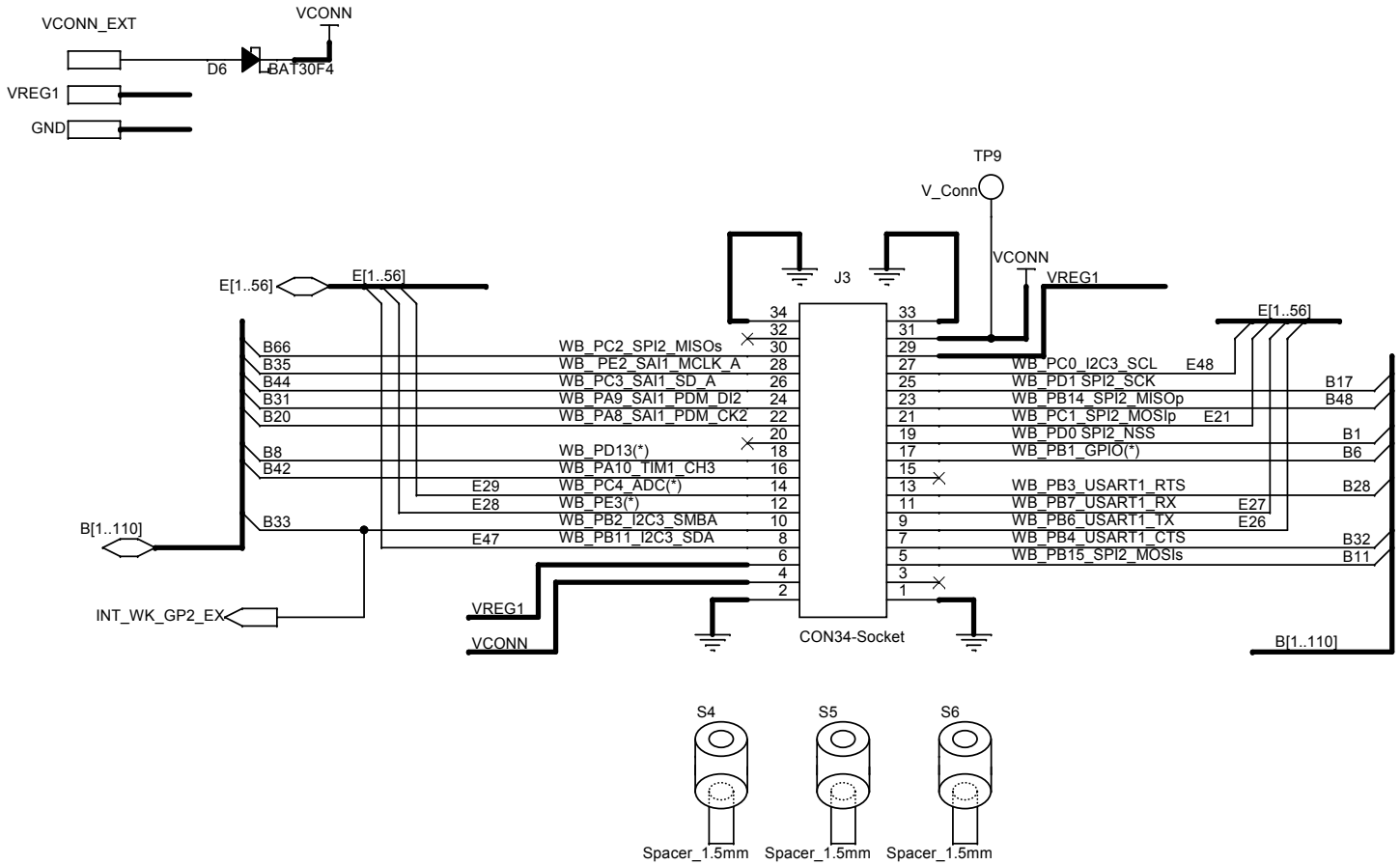


Figure 27. STDES-CBMLoRaBLE schematic diagram (5 of 10) – Main board/Interface

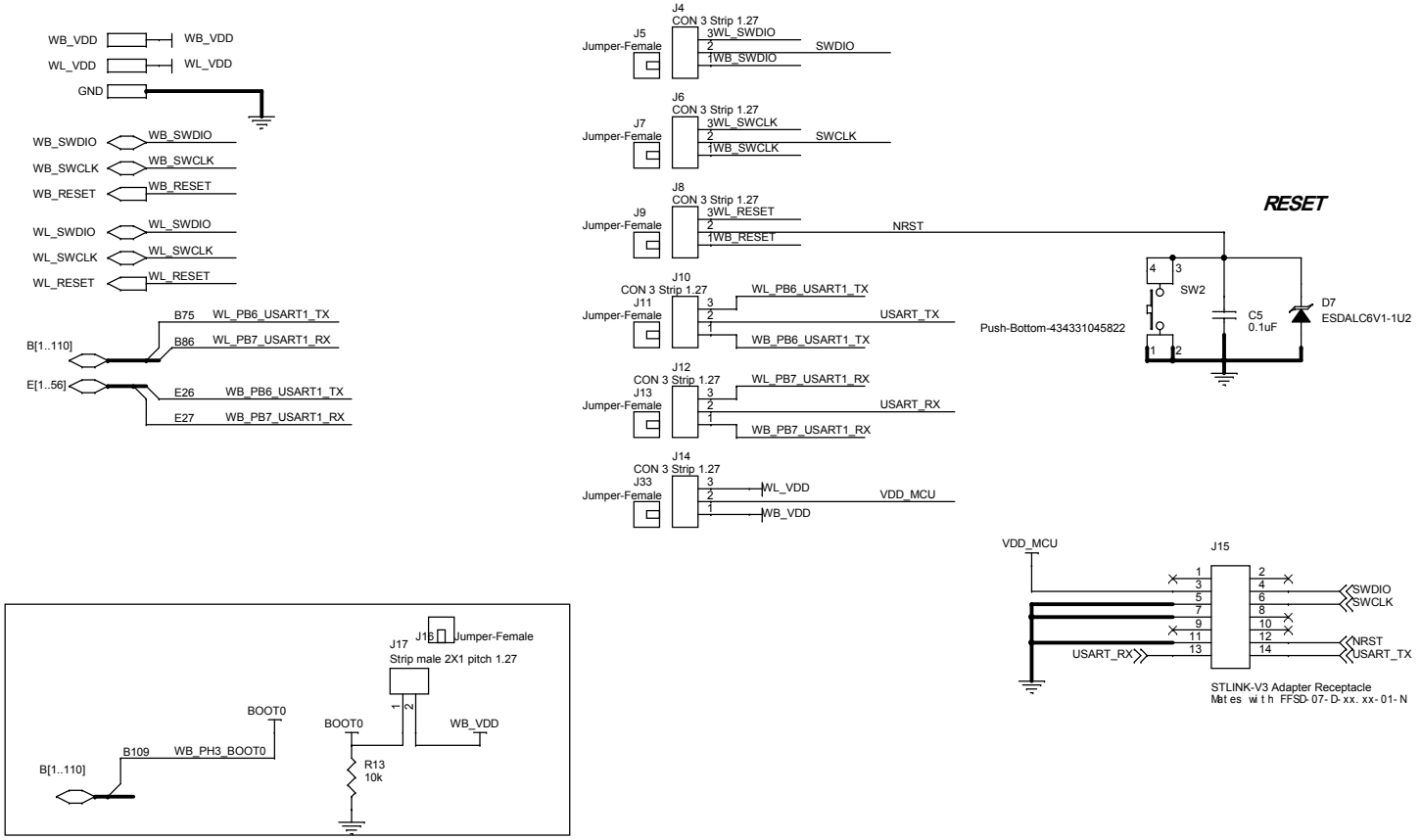


Figure 28. STDES-CBMLoRaBLE schematic diagram (6 of 10) – Main board/Memory&Secure

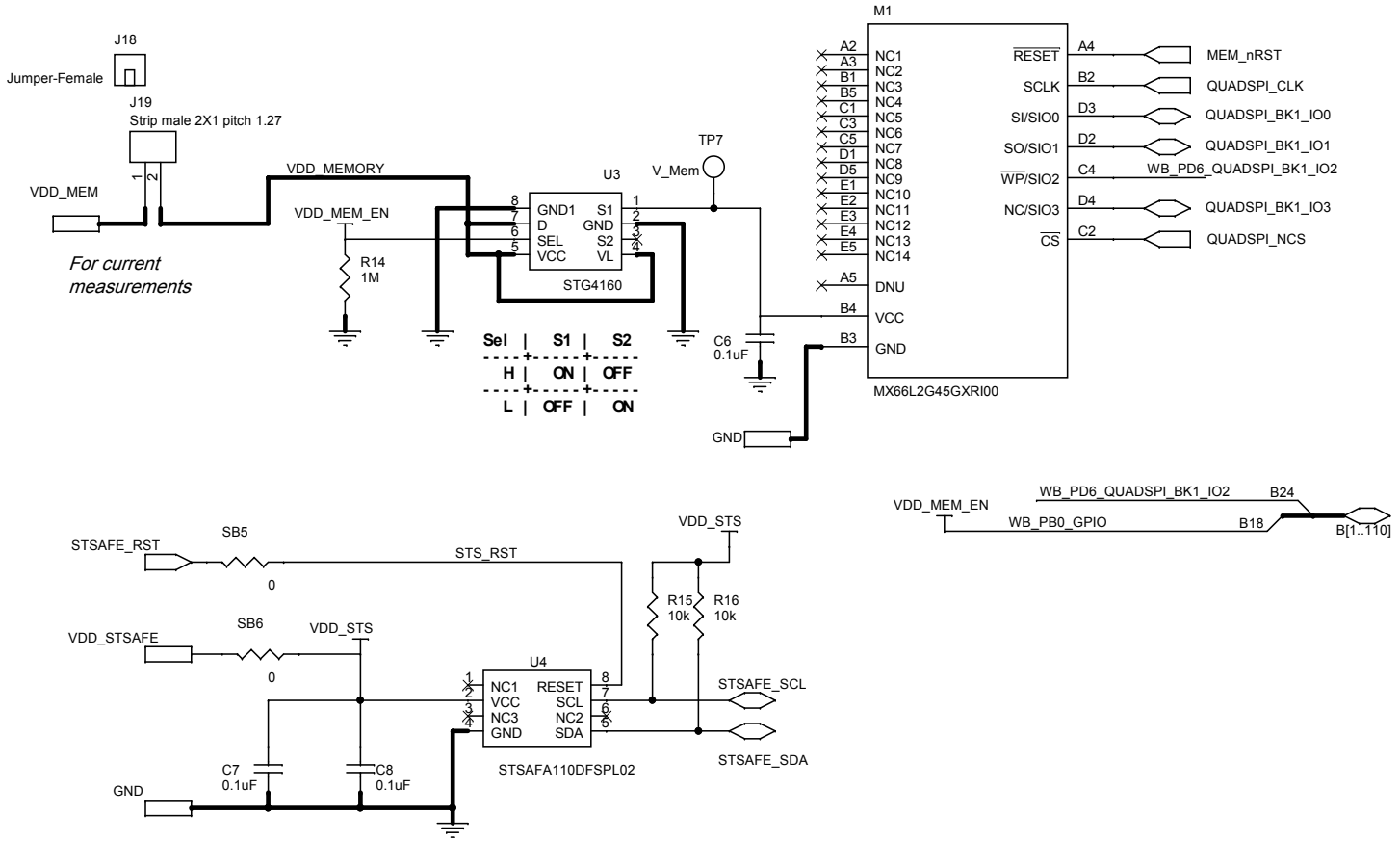


Figure 29. **STDES-CBMLoRaBLE schematic diagram (7 of 10) – Main board/PW_IND**

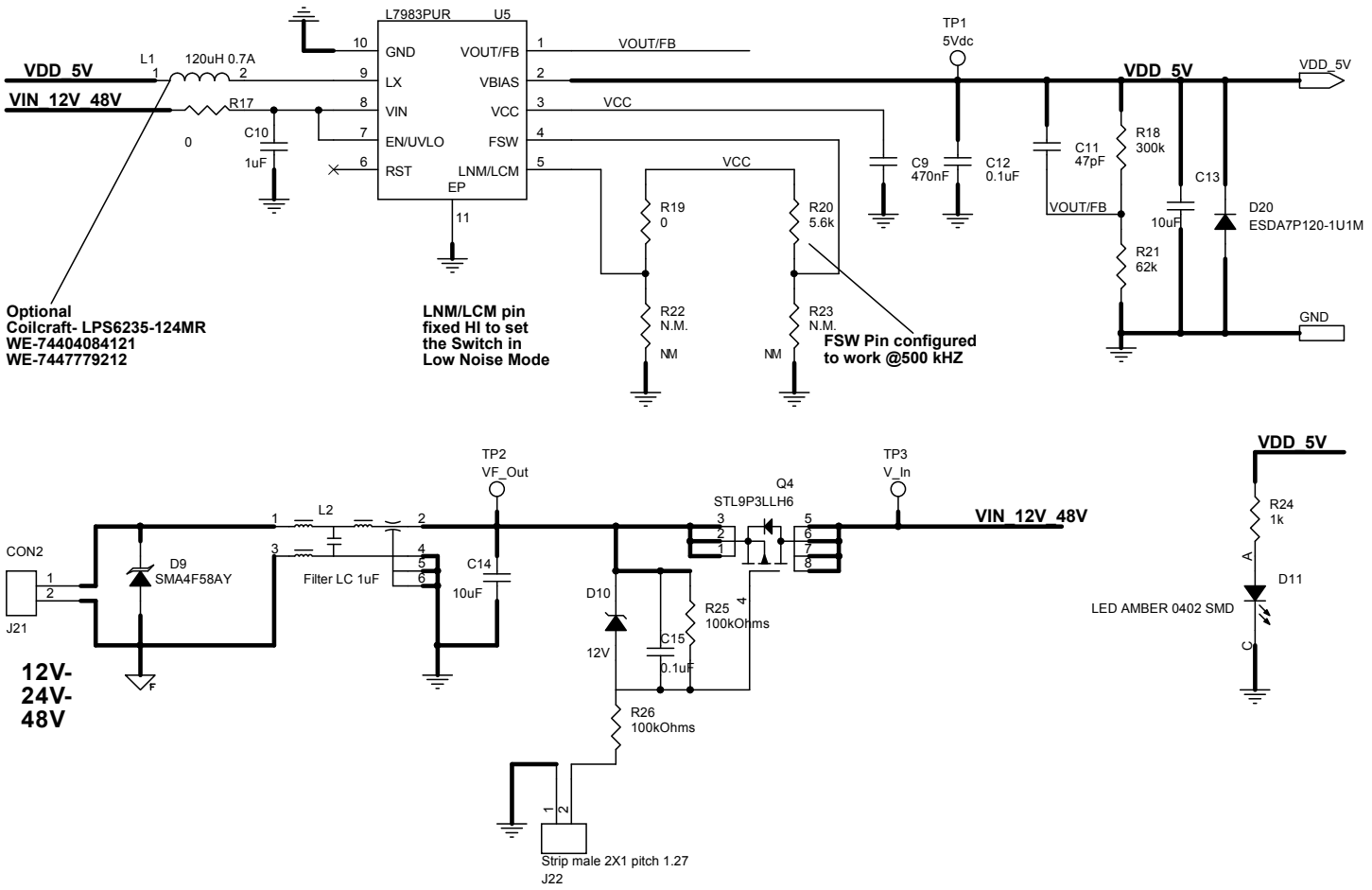


Figure 30. **STDES-CBMLoRaBLE schematic diagram (8 of 10) – Main board/PWR_TOP**

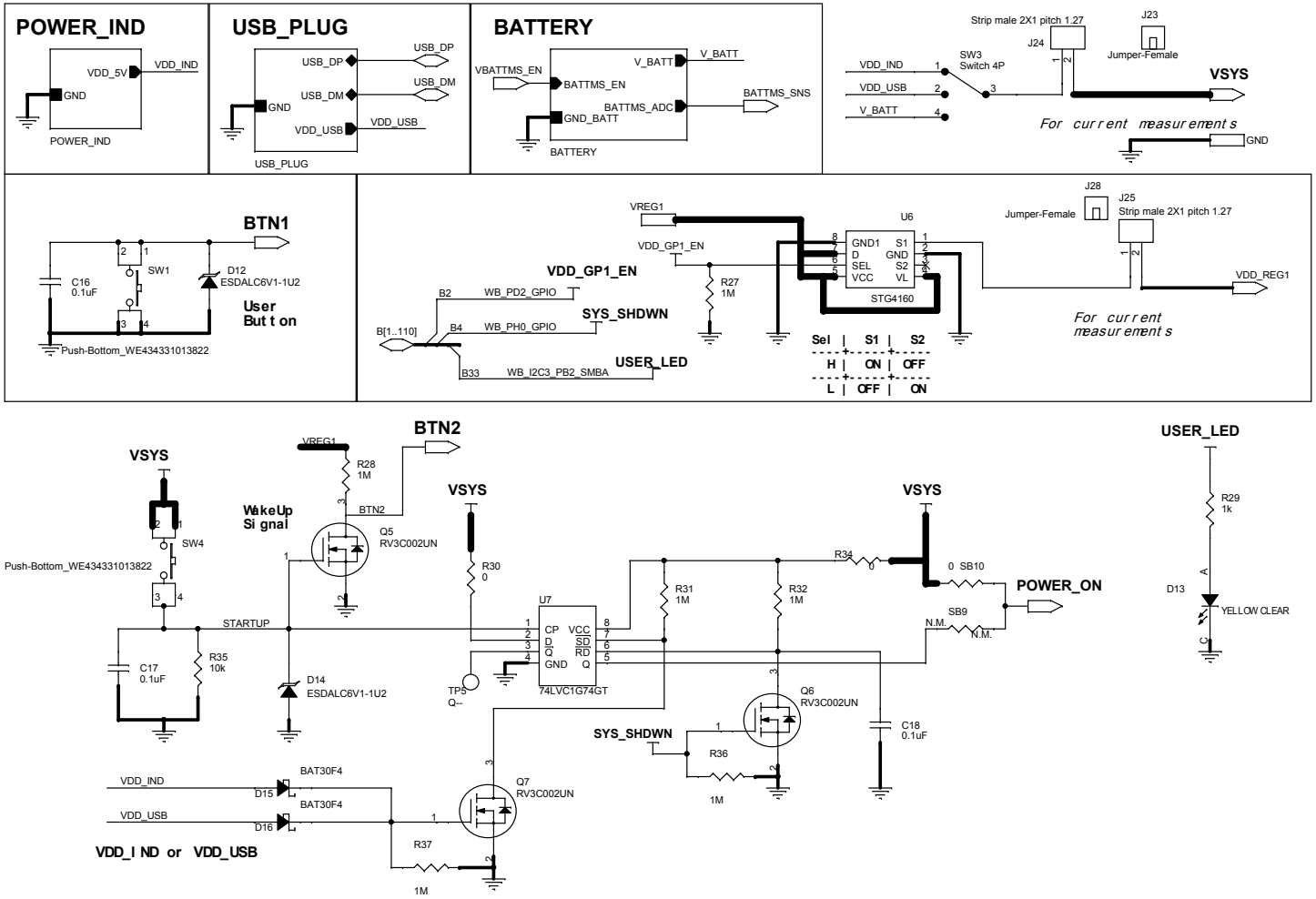


Figure 31. STDES-CBMLoRaBLE schematic diagram (9 of 10) – Main board/SoB_WB_WL

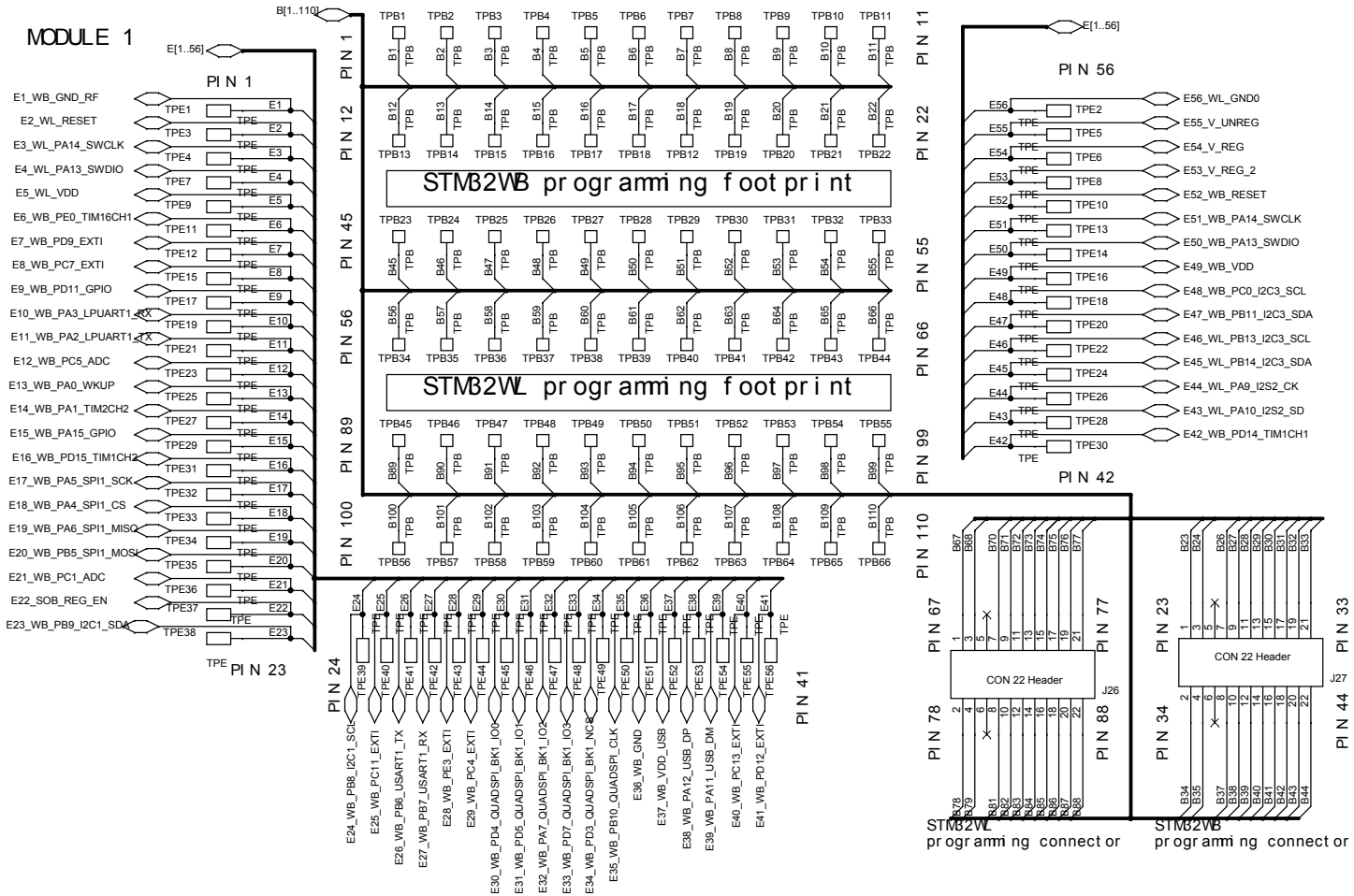


Figure 32. STDES-CBMLoRaBLE schematic diagram (10 of 10) – Main board/USB_PLUG

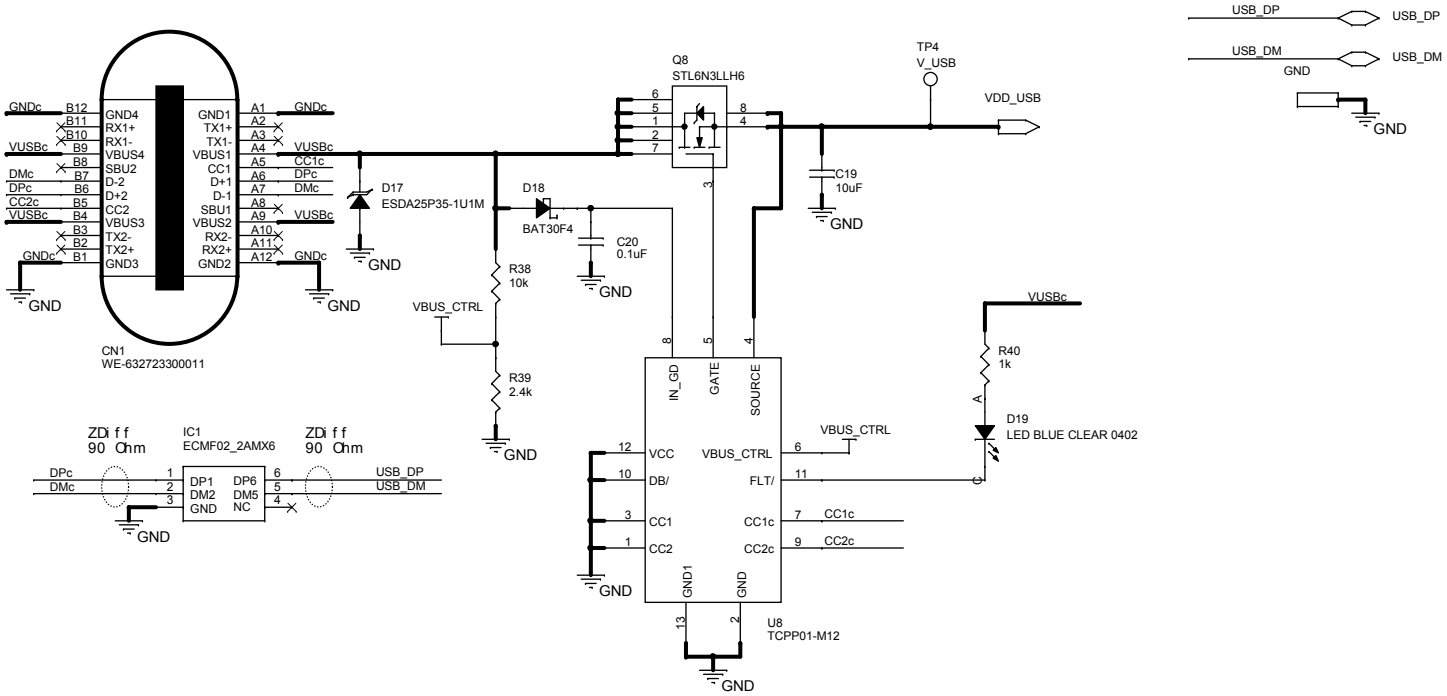


Figure 33. STDES-CBMLoRaBLE Schematic – Expansion board 1

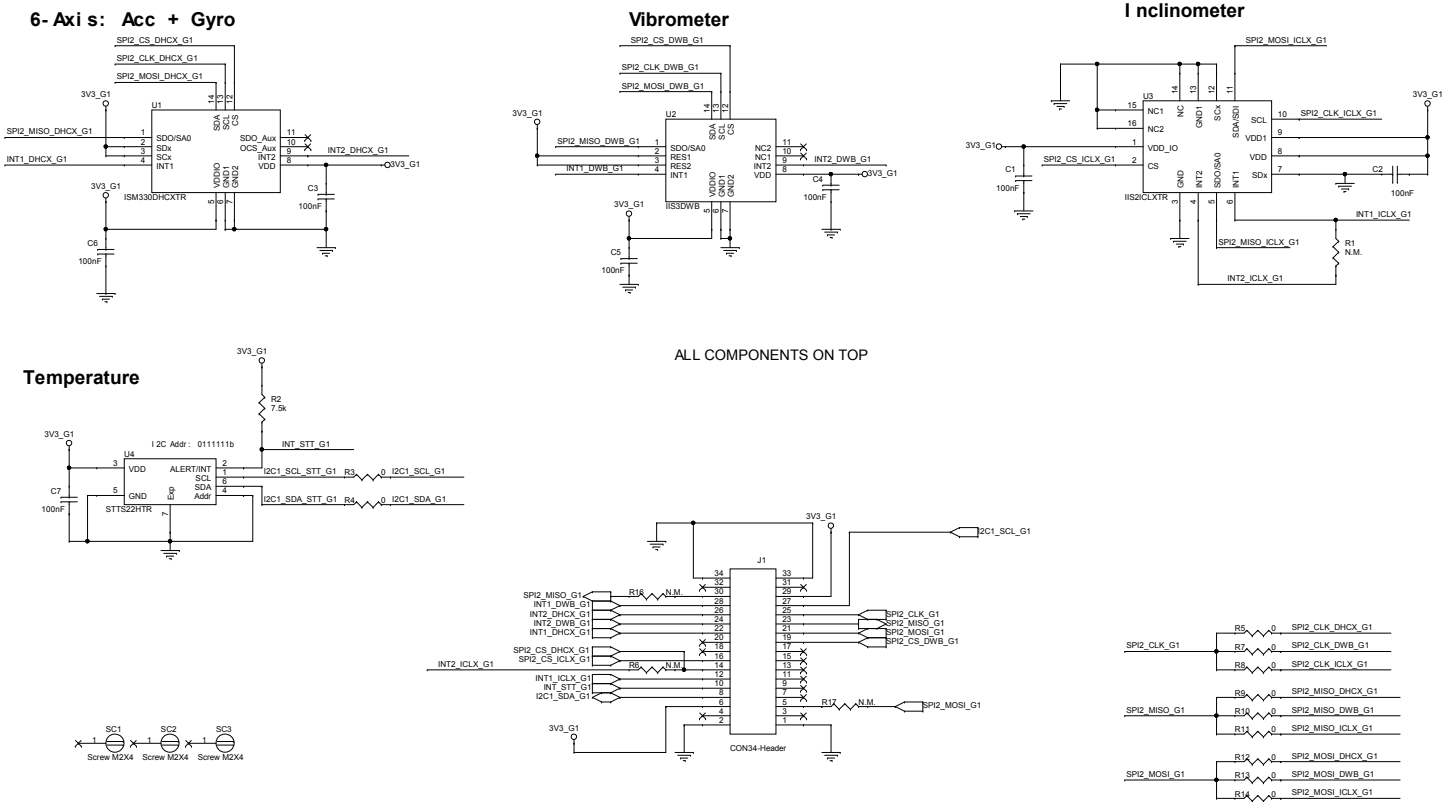


Figure 34. STDES-CBMLoRaBLE Schematic – Expansion board 2

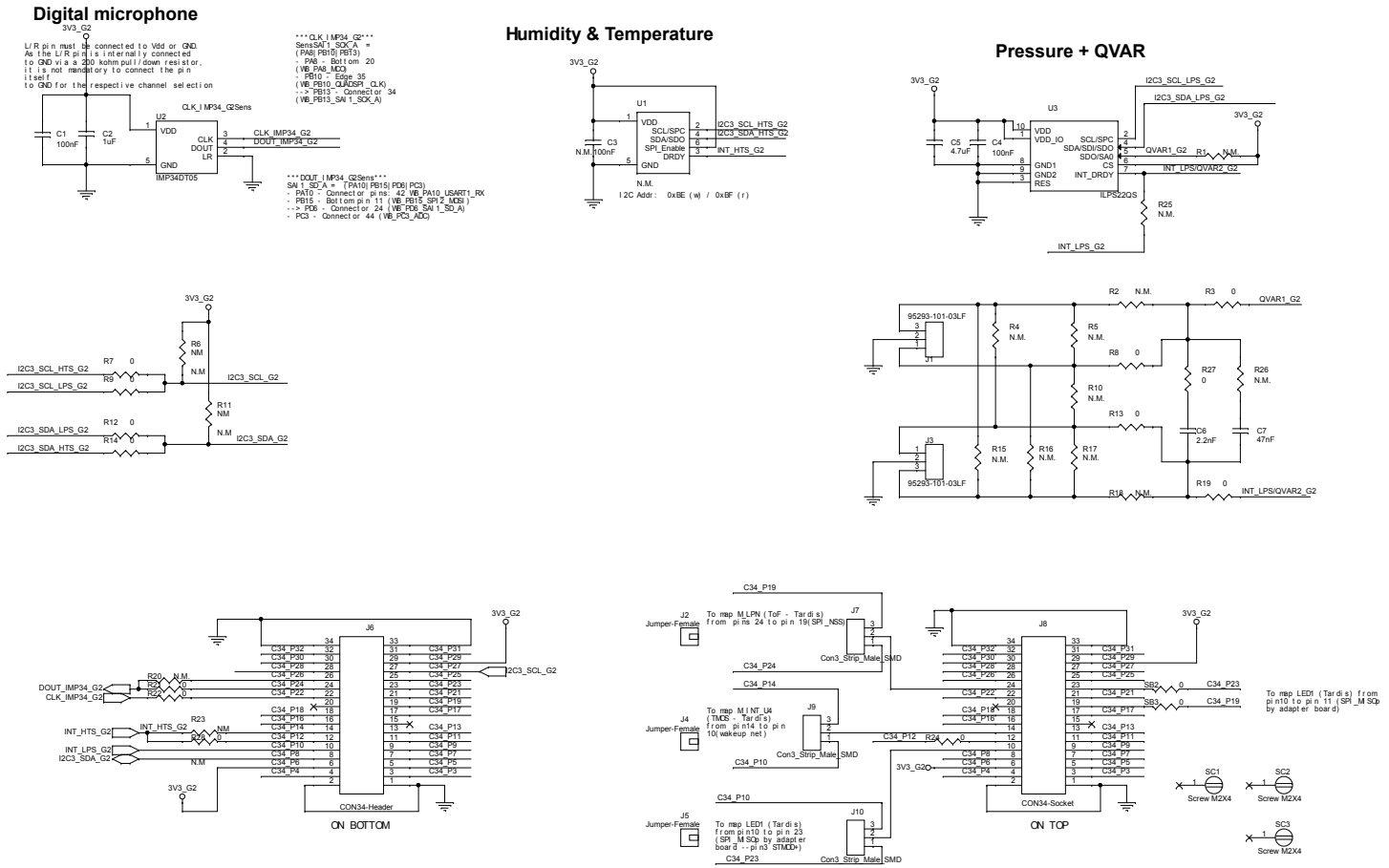


Figure 35. System on board circuit schematic (1 of 9)

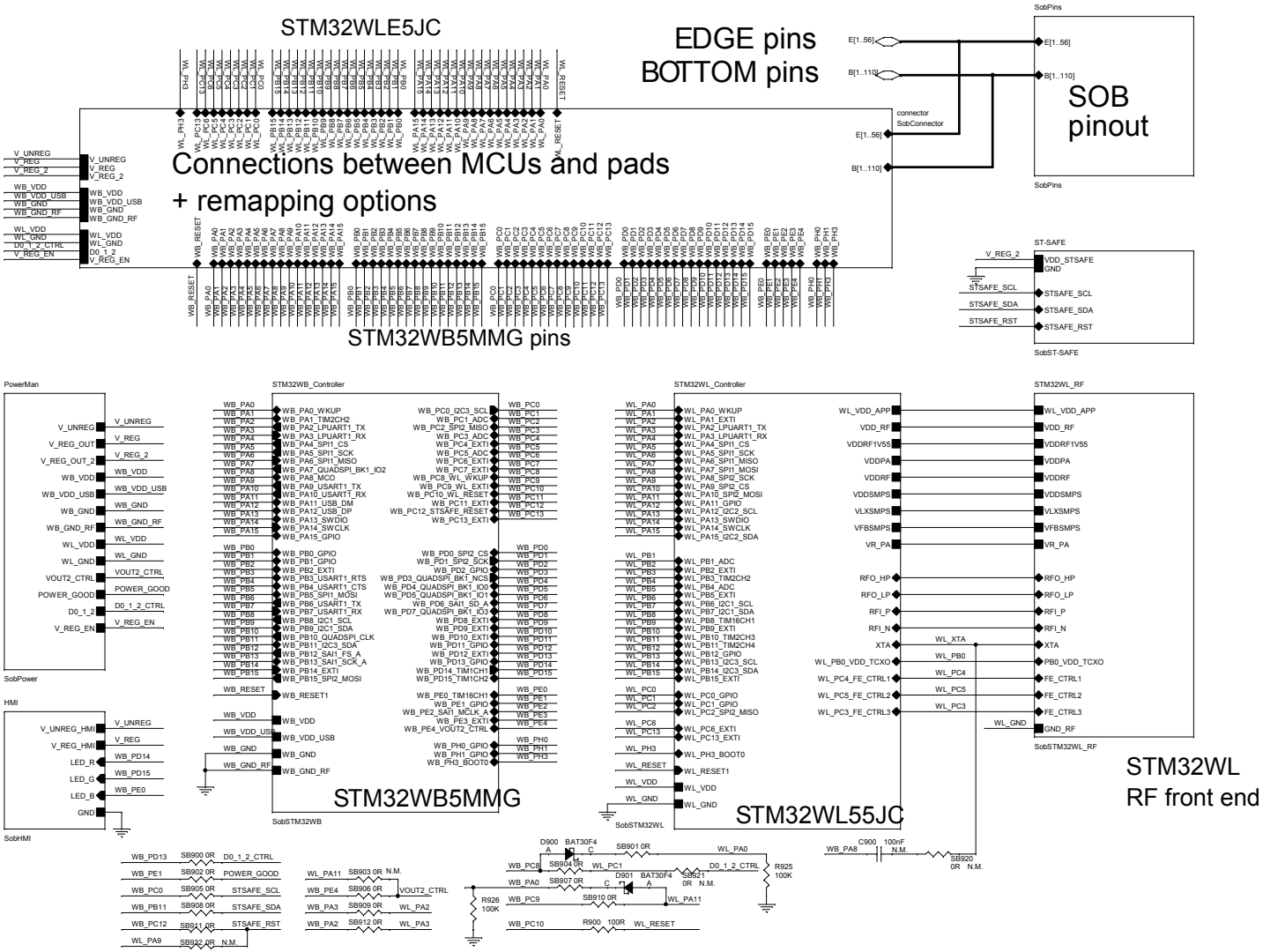


Figure 36. **System on board circuit schematic (2 of 9)**

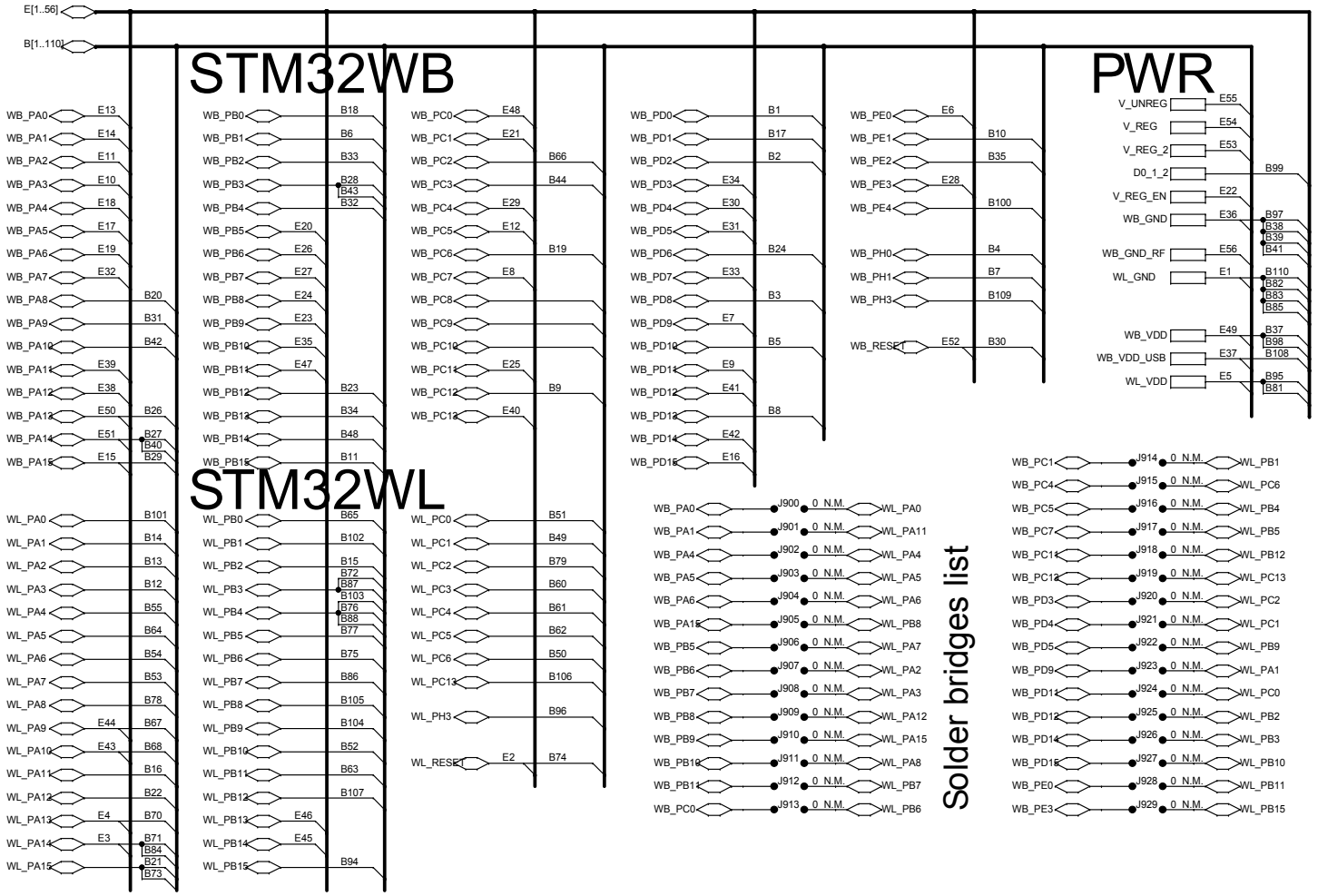


Figure 37. System on board circuit schematic (3 of 9)

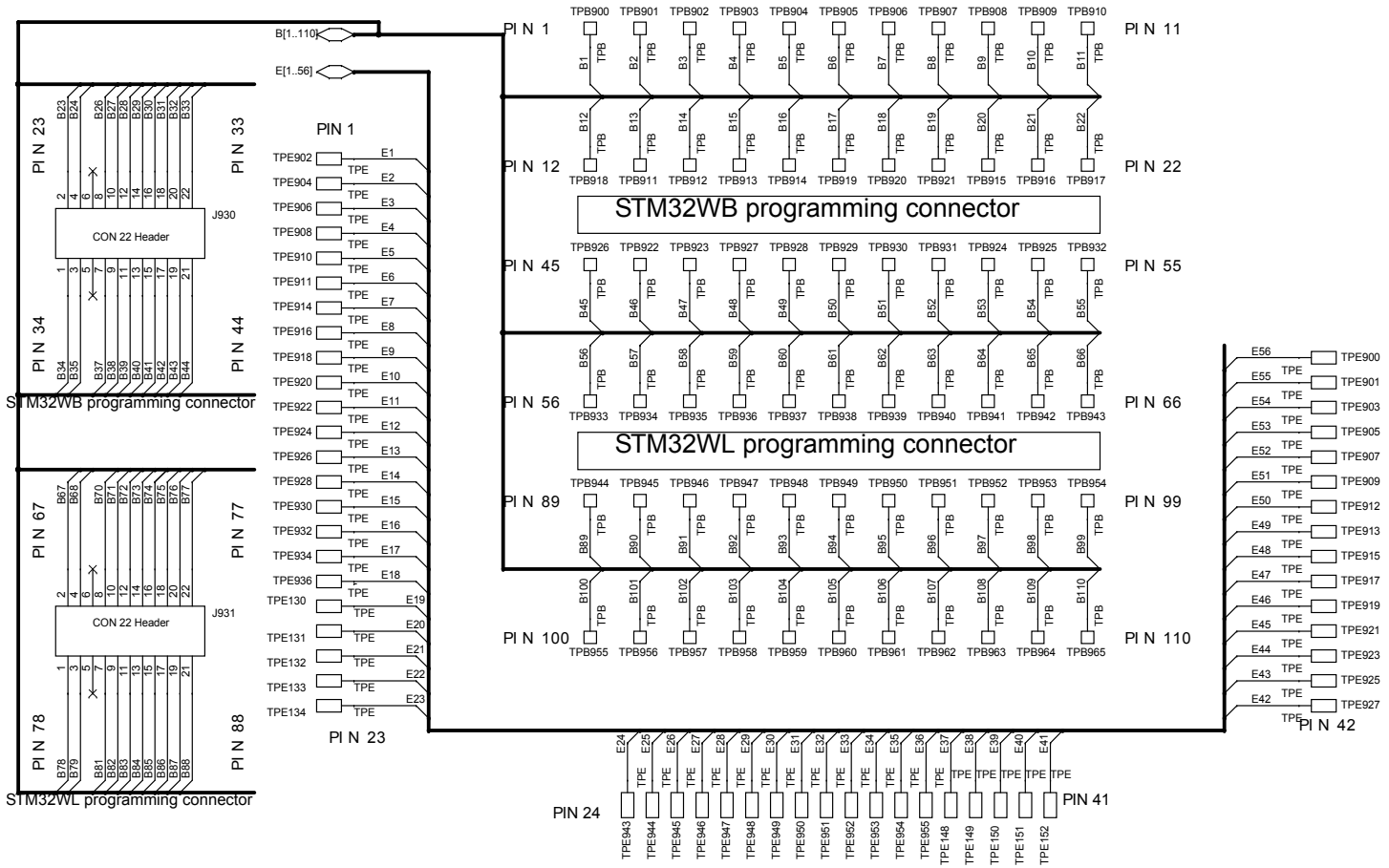
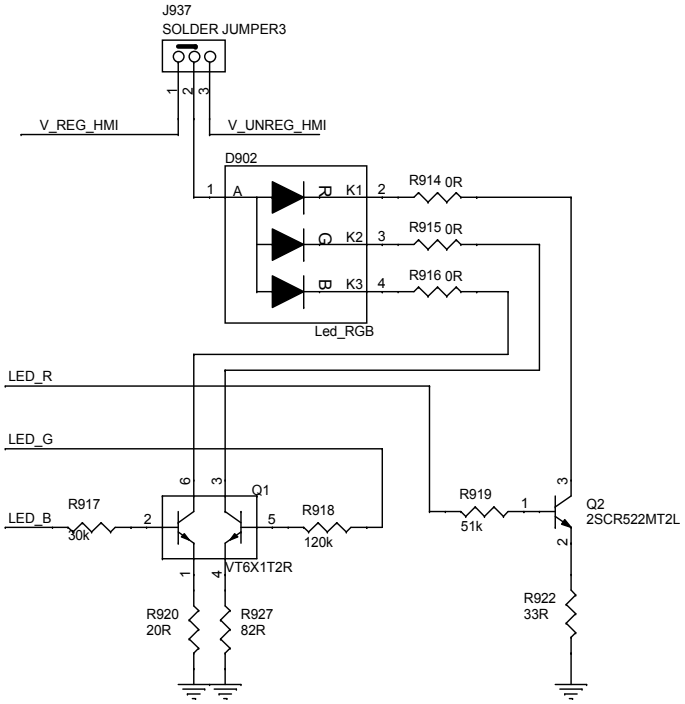


Figure 38. System on board circuit schematic (4 of 9)



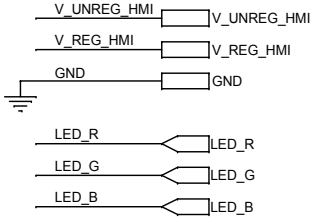


Figure 39. System on board circuit schematic (5 of 9)

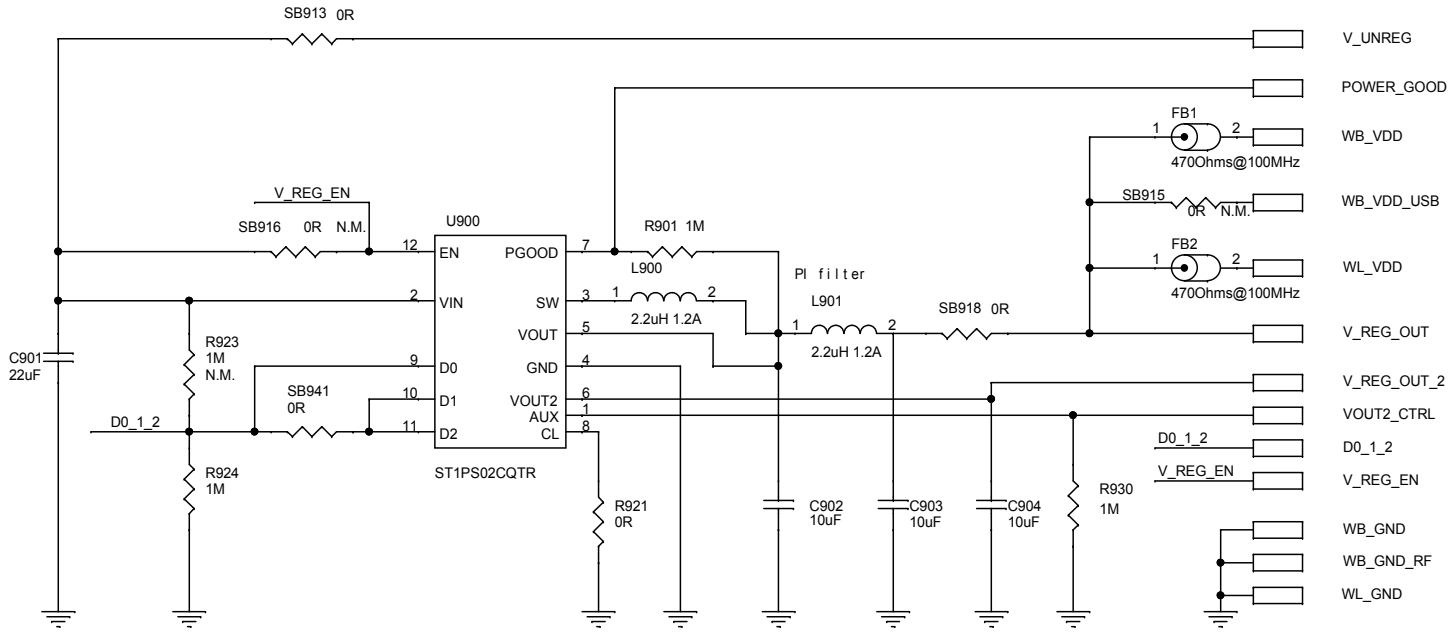


Figure 40. System on board circuit schematic (6 of 9)

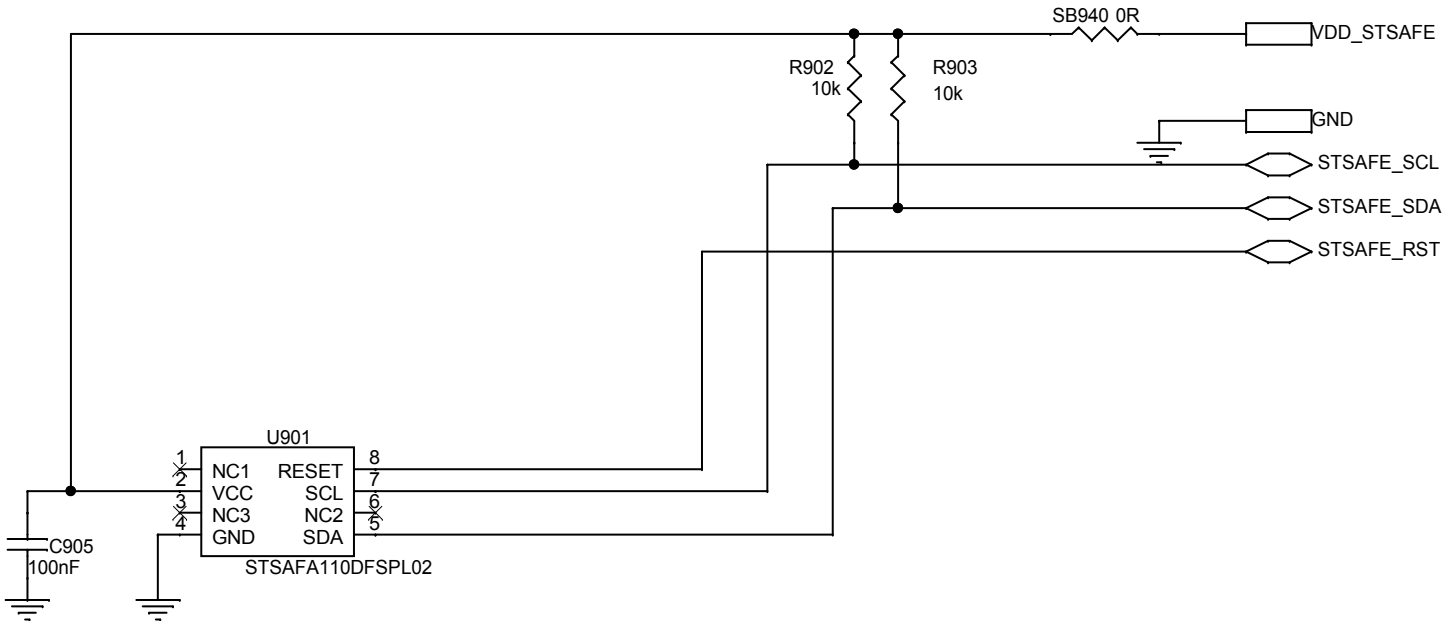


Figure 41. System on board circuit schematic (7 of 9)

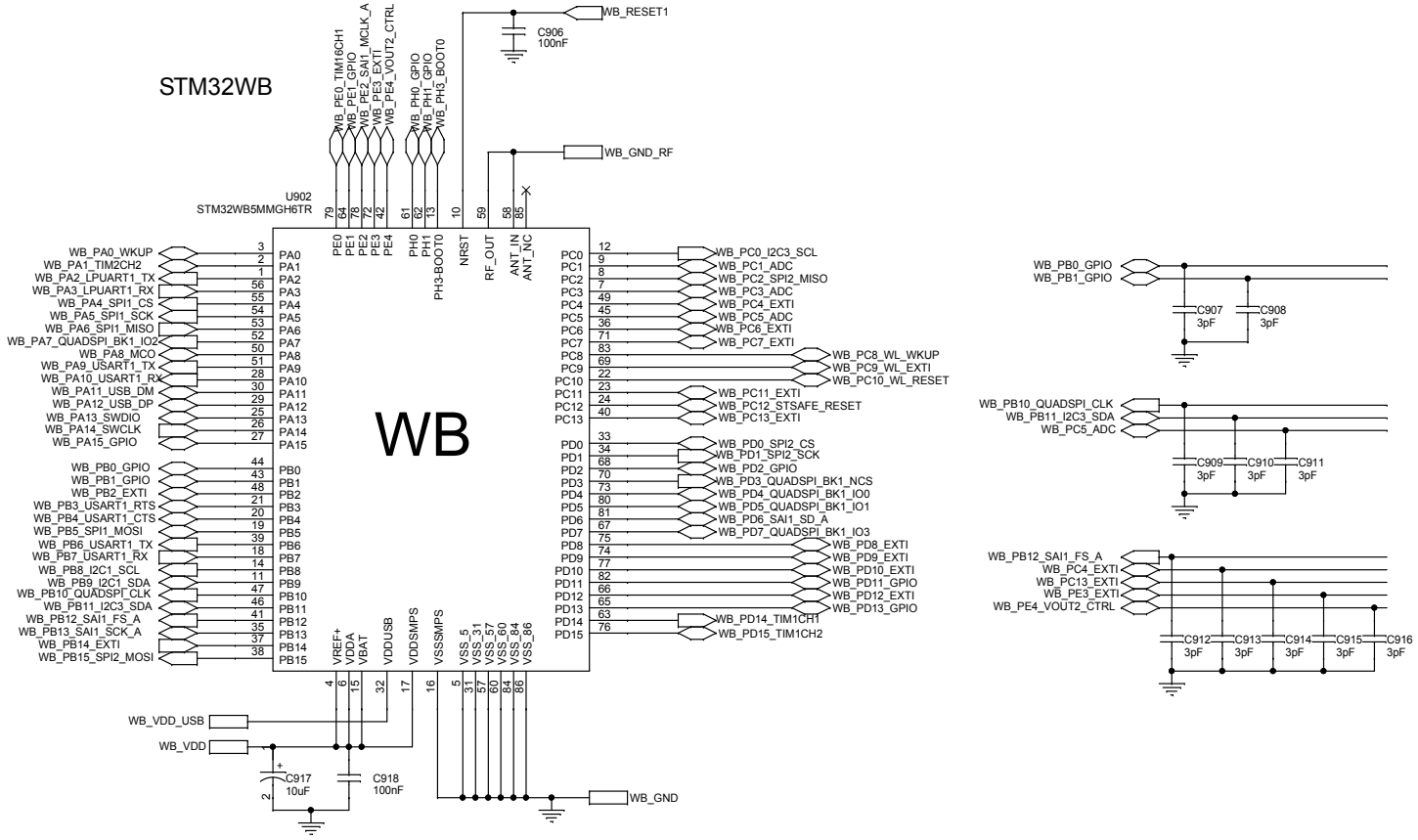


Figure 42. System on board circuit schematic (8 of 9)

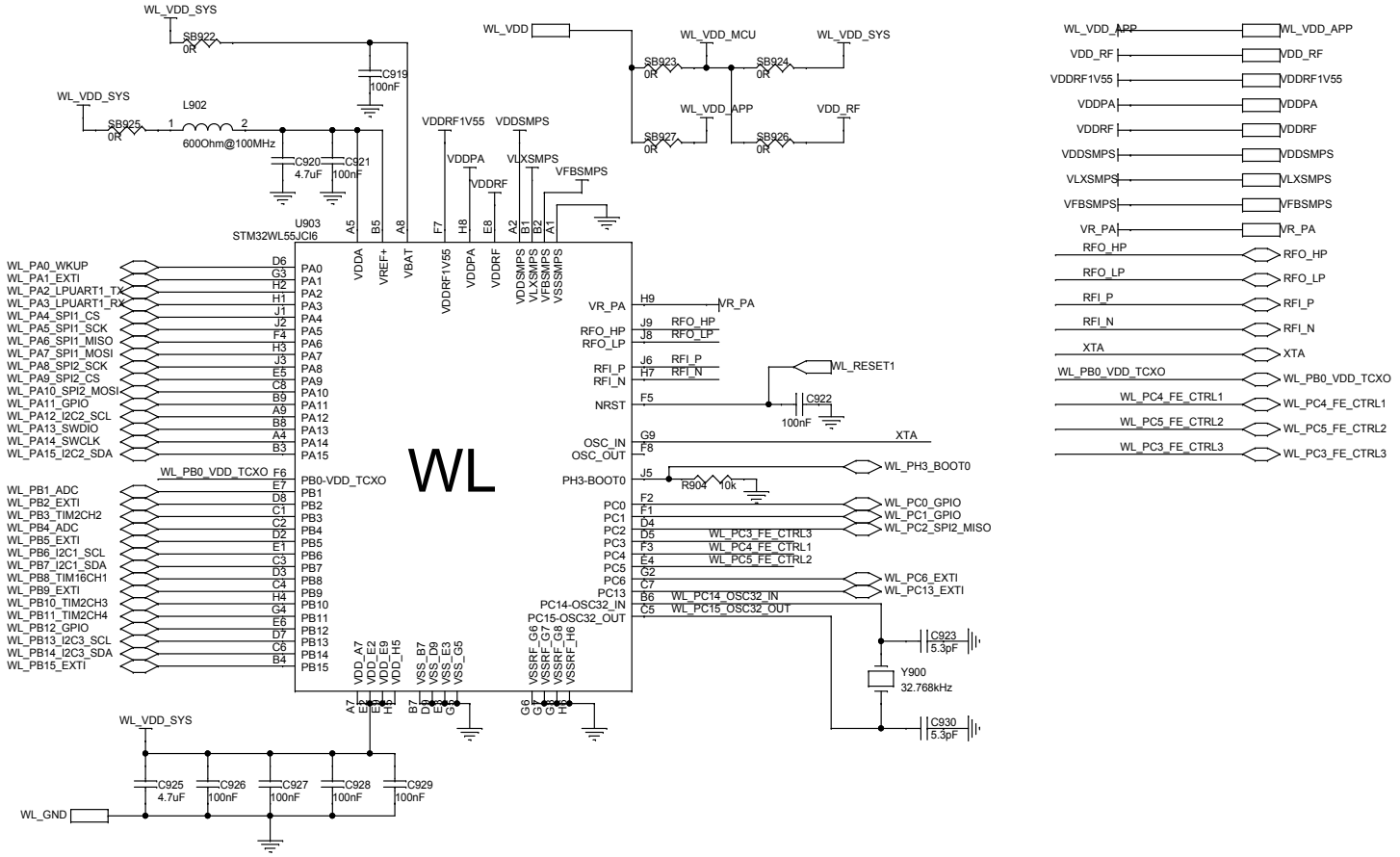


Figure 43. System on board circuit schematic (9 of 9)

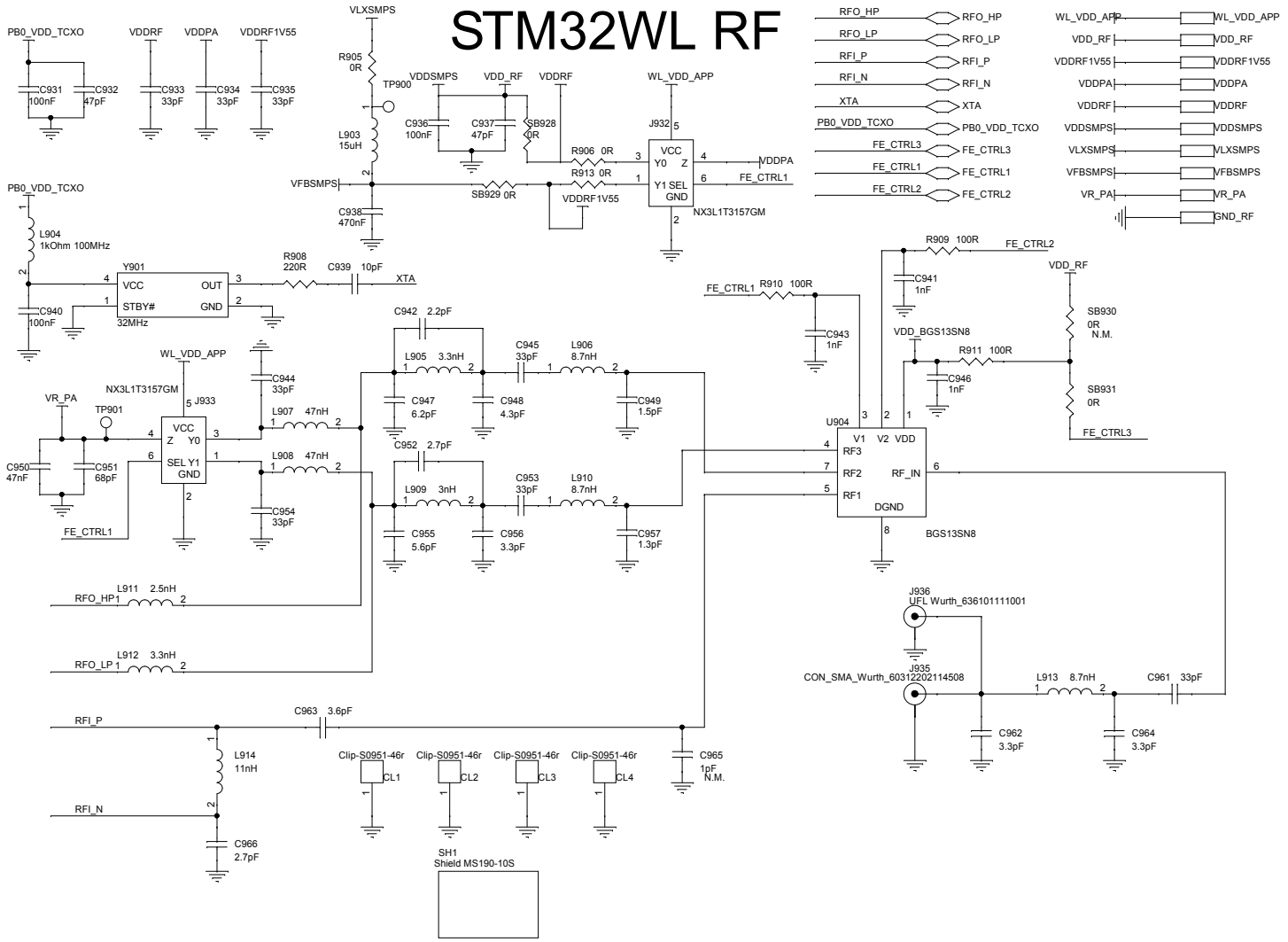


Figure 44. Flexible cable 1 circuit schematic

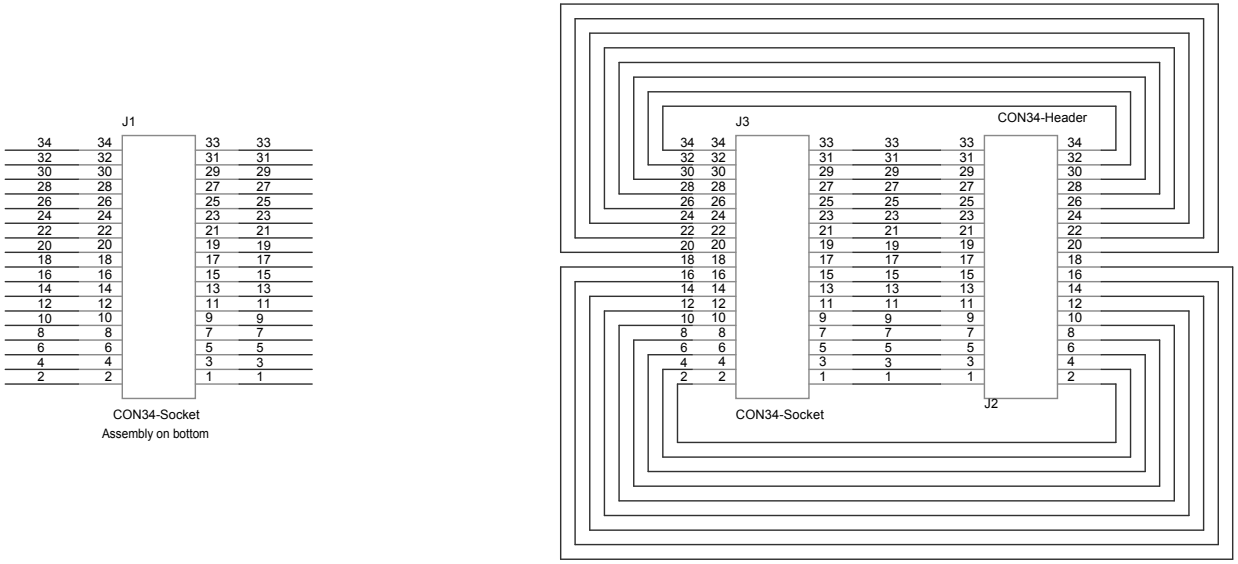
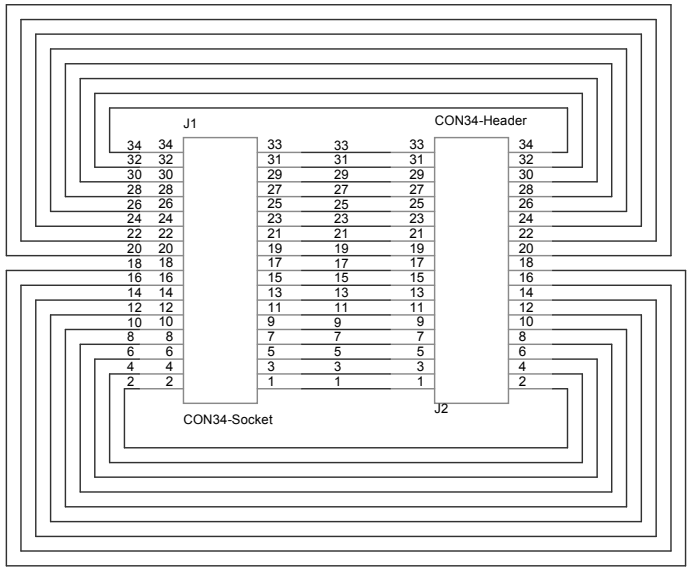


Figure 45. Flexible cable 2 circuit schematic



6 Bill of materials

Table 3. STDES-CBMLoRaBLE bill of materials

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
1	1	Table 4	-	Main board	ST	Not available for sale
2	1	Table 5	-	Expansion board no. 1	ST	Not available for sale
3	1	Table 6	-	Expansion board no. 2	ST	Not available for sale
4	1	Table 7	-	System on board	ST	Not available for sale
5	1	Table 8	-	Flexible cable no. 1	ST	Not available for sale
6	1	Table 9	-	Flexible cable no. 2	ST	Not available for sale

Table 4. STDES-CBMLoRaBLE: main board bill of materials

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
1	1	C1	1uF	CAP CER 1UF 6.3V X5R 0402	Taiyo Yuden	JMK105BJ105KV-F
2	10	C5 C6 C7 C8 C12 C15 C16 C17 C18 C20	0.1uF	CAP CER 0.1UF 16V X7R 0402	Würth Elektronik	885012205037
3	1	C9	470nF	CAP CER 0.47UF 25V X7R 0603	Wurth Electronics Inc.	885012206075
4	1	C10	1uF	CAP CER 1UF 100V X7R 1206	TDK Corporation	C3216X7R2A105K160AA
5	1	C11	47pF	CAP CER 47PF 50V C0G 0603	TDK Corporation	C1608C0G1H470J080AA
6	1	C13	10uF	CAP CER 10UF 10V X5R 0402	Samsung Electro-Mechanics America, Inc.	CL05A106MP8NUB8
7	1	C14	10uF	CAP CER 10UF 75V X7R 1210	TDK Corporation	CGA6P1X7R1N106M250AC
8	1	C19	10uF	CAP CER 10UF 6.3V X5R 0603	TDK Corporation	C1608X5R0J106M080AB
9	1	CN1	WE-632723300011	USB 3.1 TYPE C RECEPTACLE THT/SM	Wurth Electronics Inc.	632723300011
10	9	D1 D2 D3 D4 D5 D6 D15 D16 D18	BAT30F4, ST0201	30 V, 300 mA CSP general purpose Small Signal Schottky Diode	ST	BAT30F4
11	3	D7 D12 D14	ESDALC6V1-1U2, ST0201	Single-line low capacitance Transil for ESD protection	ST	ESDALC6V1-1U2

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
12	1	D9	SMA4F58AY	Automotive 400 W TVS in SMA Flat	ST	SMA4F58AY
13	1	D10	12V	DIODE ZENER 12V 500MW SOD123	ON Semiconductor	MMSZ5242BT1G
14	1	D11	LED AMBER 0402 SMD	LED AMBER 0402 SMD	Wurth Electronics	150040AS73240
15	1	D13	LED YELLOW CLEAR 0402 SMD	LED YELLOW CLEAR 0402 SMD	Würth Elektronik	150040YS73240
16	1	D17	ESDA25P35-1U 1M, QFN-2L	High-power transient voltage suppressor	ST	ESDA25P35-1U1M
17	1	D19	LED BLUE CLEAR 0402	LED BLUE CLEAR 0402 SMD	Würth Elektronik	150040BS73240
18	2	D20 D21	ESDA7P120-1U 1M, QFN-2L	High-power transient voltage suppressor	ST	ESDA7P120-1U1M
19	1	IC1	ECMF02-2AMX 6, QFN-6L	Common-mode filter and ESD protection for USB 2.0 and MIPI/MDDI interfaces	ST	ECMF02-2AMX6
20	1	J1	Con2-Wurth65530212 4022	CONN HEADER SMD 2POS 1MM	Würth Elektronik	665302124022
21	2	J2 J3	CON34-Socket	CONN SOCKET 34POS SMD GOLD	Panasonic Electric Works	AXF5G3412A
22	6	J4 J6 J8 J10 J12 J14	CON 3 Strip 1.27	CONN HEADER VERT 3POS 1.27MM	Harwin Inc.	M50-3530342
23	10	J5 J7 J9 J11 J13 J16 J18 J23 J28 J33	Jumper-Female	CONN JUMPER SHORTING 1.27MM GOLD	Sullins Connector Solutions	NPB02SVAN-RC
24	1	J15	STLINK-V3 Adapter Receptacle	CONN HEADER SMD 14POS 1.27MM	Samtec Inc.	FTSH-107-01-L-DV-K
25	5	J17 J19 J22 J24 J25	Strip male 2X1 pitch 1.27	CONN HEADER VERT 2POS 1.27MM	Harwin Inc.	M50-3530242
26	1	J21	CON2	CONN TERM BLOCK 2.54MM 2POS	Phoenix Contact	1725656
28	2	J26 J27	CON 22 Header	CONN HEADER SMD 22POS 1.27MM	Samtec Inc.	FTSH-111-01-L-DV-K-P-TR
29	1	L1	120uH 0.7A	FIXED IND 120UH 670MA 660 MOHM	Würth Elektronik	744777212

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
30	1	L2	Filter LC 1uF	FILTER LC 1UF SMD	Murata Electronics	BNX022-01L
31	1	M1	MX66L2G45GXRI00	IC FLASH SERIAL NOR 2GBIT	Macronix	MX66L2G45GXRI00
32	1	Q4	STL9P3LLH6, PowerFLAT 3.3x3.3	P-channel -30 V, 12 mOhm typ., -9 A STripFET H6 Power MOSFET in a PowerFLAT 3.3 x 3.3 package	ST	STL9P3LLH6
33	3	Q5 Q6 Q7	RV3C002UN	NCH 20V 150MA SM SIG MOSFET, VML	Rohm Semiconductor	RV3C002UNT2CL
34	1	Q8	STL6N3LLH6, PowerFLAT 2x2	N-channel 30 V, 0.021 Ohm typ., 6 A STripFET H6 Power MOSFET in a PowerFLAT 2x2 package	ST	STL6N3LLH6
35	1	R1	36k	RES SMD 36K OHM 1% 1/10W 0603	Yageo	RC0603FR-0736KL
36	8	R2 R14 R27 R28 R31 R32 R36 R37	1M	RES SMD 1M OHM 1% 1/16W 0402	TE CONNECTIVITY	CRG0402F1M0
37	1	R3	100k	RES SMD 100K OHM 5% 1/10W 0603	Stackpole Electronics Inc	RMCF0603FT100K
38	5	R13 R15 R16 R35 R38	10K	RES SMD 10K OHM 1% 1/16W 0402	Yageo	AC0402FR-0710KL
39	1	R17	0	RES SMD 0 OHM JUMPER 1/10W 0603	Panasonic Electronic Components	ERJ-3GEY0R00V
40	1	R18	300k	CHIP RESISTOR SMD 1% 1/10W 0603	Bourns	CR0603-FX-3003ELF
41	7	R19 R22 R23 R30 R34 SB2 SB3	0	RES SMD 0 OHM JUMPER 1/16W 0402	Vishay Dale	CRCW04020000Z0ED
42	1	R20	5.6k	RES SMD 5.6K OHM 0.05% 1/8W 0603	Panasonic Electronic Components	ERA-3VRW5601V
43	1	R21	62k	RES SMD 62K OHM 0.1% 1/10W 0603	Yageo	RT0603BRD0762KL
44	3	R24 R29 R40	1k	RES SMD 1K OHM 5% 1/16W 0402	Yageo	RC0402JR-071KL
45	2	R25 R26	100kOhms	RES SMD 100K OHM 1% 1/16W 0402	Yageo	RC0402FR-07100KL

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
46	1	R39	2.4k	CHIP RESISTOR SMD 1% 1/16W 0402	Yageo	RC0402FR-072K4L
47	6	S1 S2 S3 S4 S5 S6	Spacer_1.5mm	RND STANDOFF M2X0.4 STEEL 1.5MM	Würth Elektronik	9774015243R
48	2	SB1 SB4	N.M.	RES SMD 0402 - NOT MOUNTED	-	-
49	4	SB5 SB6 SB9 SB10	0	0 OHM JUMPER 0603	Panasonic Electronic Components	ERJ-3GEY0R00V
50	2	SW1 SW4	Push-Bottom_WE434 331013822	SWITCH TACTILE SPST-NO 0.05A 12V	Würth Elektronik	434331013822
51	1	SW2	Push-Bottom-434331 045822	SWITCH TACTILE SPST-NO 0.05A 12V	Würth Elektronik	434331045822
52	1	SW3	Switch 4P	Slide Switches Slide Type 1P4T (1.4mm height)	Diptronics	MSS4-V-T/R
53	4	TP1 TP2 TP3 TP4	5Vdc	TEST POINT PC MINI .040"D BLACK	Keystone Electronics	5001
54	3	U1 U3 U6	STG4160	Analog Switch ICs LV 0.5 Ohm SPDT 15kV 1.65 to 4.8V 0.2uA	STMicroelectron ics	STG4160BJR
55	1	U4	STSAFA110DF SPL02, UFDFPN 8 2x3x0.6	Authentication, state-of-the-art security for peripherals and IoT devices	ST	STSAFA110DFSPL02
56	1	U5	L7983PUR, DFN 3X3X0.8 10L PITCH 0.5	60 V 300 mA synchronous step-down switching regulator with 10 µA quiescent current	ST	L7983PUR
57	1	U7	74LVC1G74GT	IC FF D-TYPE SNGL 1BIT 8XSON	Nexperia USA Inc.	74LVC1G74GT,115
58	1	U8	TCPP01-M12	USB Type-C® port protection for sink applications	ST	TCPP01-M12
59	1	MODULE 1	-	Board WWB_WL_SOB	ST	-

Table 5. STDES-CBMLoRaBLE: expansion board no. 1 bill of materials

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
1	7	C1 C2 C3 C4 C5 C6 C7	100nF	CAP CER 0.1UF 16V X7R 0402	Murata Electronics North America	GRM155R71C104KA88J
2	1	J1	CON34-Header	CONN HDR 34POS SMD GOLD	Panasonic Electric Works	AXF6G3412A
3	4	R1 R6 R16 R17	N.M.	RES SMD 0402 - NOT MOUNTED	-	-
4	1	R2	7.5k	CHIP RESISTOR SMD 1% 1/16W 0402	-	-
5	11	R3 R4 R5 R7 R8 R9 R10 R11 R12 R13 R14	0	RES SMD 0 OHM JUMPER 1/16W 0402	Vishay Dale	CRCW04020000Z0ED
6	3	SC1 SC2 SC3	Screw M2X4	MACH SCREW PAN SLOTTED M2X4mm	RS	914-1462
7	1	U1	ISM330DHCXTR, VFLGA2.5X3X.86 14L P.5 L.475X.25	NEMO inertial module with Machine Learning Core, Finite State Machine with digital output for industrial applications	ST	ISM330DHCXTR
8	1	U2	IIS3DWBTR, VFLGA2.5X3X.86 14L P.5 L.475X.25	Ultra-wide bandwidth, low-noise 3-axis digital accelerometer	ST	IIS3DWBTR
9	1	U3	IIS2ICLXTR, LGA 5X5X1.7 16LD CERAMIC CAVITY	High-accuracy, High-resolution, Low-power, 2-axis Digital Inclinometer with Embedded Machine Learning Core	ST	IIS2ICLXTR
10	1	U4	STTS22HTR, UDFN 2X2X.55 6L PITCH0.65	Low-voltage, ultra-low-power, 0.5°C accuracy I2C/SMBus 3.0 temperature sensor	ST	STTS22HTR

Table 6. STDES-CBMLoRaBLE: expansion board no. 2 bill of materials

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
1	2	C1 C4	100nF	CAP CER 0.1UF 16V X7R 0402	Murata Electronics North America	GRM155R71C104KA88J
2	1	C3	100nF	CAP CER 0.1UF 16V X7R 0402	Murata Electronics North America	GRM155R71C104KA88J

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
3	1	C2	1uF	CAP CER 1UF 6.3V X5R 0402	Taiyo Yuden	JMK105BJ105KV-F
4	1	C5	4.7uF	CAP CER 4.7UF 10V X5R 0603	Wurth Electronics Inc.	885012106012
5	1	C6	2.2nF	CAPACITOR CERAMIC SMD 0603	Wurth Electronics Inc.	885012206061
6	1	C7	47nF	CAPACITOR CERAMIC SMD 0603	Wurth Electronics Inc.	885012206063
7	2	J1 J3	95293-101-03LF	CONN HEADER SMD 3POS 2.54MM	Amphenol ICC (FCI)	95293-101-03LF
8	3	J2 J4 J5	Jumper-Female	CONN JUMPER SHORTING 1.27MM GOLD	Sullins Connector Solutions	NPB02SVAN-RC
9	1	J6	CON34-Header	CONN HDR 34POS SMD GOLD	Panasonic Electric Works	AXF6G3412A
10	3	J7 J9 J10	Con3_Strip_Male_SMD	CONN HEADER SMD 3POS 1.27MM	Sullins Connector Solutions	GRPB031VWTC-RC
11	1	J8	CON34-Socket	CONN SOCKET 34POS SMD GOLD	Panasonic Electric Works	AXF5G3412A
12	2	R1 R25	N.M.	RES SMD 0402 - NOT MOUNTED	-	-
13	9	R2 R4 R5 R10 R15 R16 R17 R18 R26	N.M.	RES SMD 0402 - NOT MOUNTED	-	-
14	13	R3 R7 R8 R9 R12 R13 R14 R19 R21 R22 R24 R27 R28	0	RES SMD 0 OHM JUMPER 1/16W 0402	Vishay Dale	CRCW04020000Z0ED
15	2	R6 R11	N.M.	CHIP RESISTOR SMD 1% 1/16W 0402	-	-
16	1	R20	N.M.	RES SMD 0402 - NOT MOUNTED	-	-
17	1	R23	N.M.	RES SMD 0 OHM JUMPER 1/16W 0402	Vishay Dale	CRCW04020000Z0ED
18	2	SB2 SB3	0	0 OHM JUMPER 0603	Yageo	RC0603JR-070RL
19	3	SC1 SC2 SC3	Screw M2X4	MACH SCREW PAN SLOTTED M2X4mm	RS	914-1462

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
20	1	U2	IMP34DT05TR, HCLGA 4MM X 3 MM X 1.00 MM MICRO	MEMS audio sensor omnidirectional digital microphone for industrial applications	ST	IMP34DT05TR
21	1	U3	ILPS22QSTR, HLGA 2X2X.8 10L EXP. SILIC .91SQ	Dual full-scale, 1260 hPa and 4060 hPa, absolute digital output barometer with embedded Qvar electrostatic sensor	ST	ILPS22QSTR

Table 7. STDES-CBMLoRaBLE: system on board bill of materials

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
1	1	C900	100nF 0201 10V 20%	CAPACITOR CERAMIC SMD 0201 10V X5R 100 nF (not mounted)	Murata Electronics	GRM033R61A104ME15D
2	1	C901	22uF 0603 (1608 Metric) 16V 20%	CAPACITOR CERAMIC SMD 0603 22 uF 16V 20% X5R	Samsung Electro-Mechanics	CL10A226MO7JZNC
3	2	C902 C903	10uF 0805 (2012 Metric) 16V 10%	CAP CER 10UF 16V X5R 0805	Murata	GRM21BR61C106KE15L
4	1	C904	10uF 0603 (1608 Metric) 6.3V 20%	CAP CER 10UF 6.3V X5R 0603	TDK Corporation	C1608X5R0J106M080AB
5	13	C905 C906 C918 C919 C921 C922 C926 C927 C928 C929 C931 C936 C940	100nF 0201 10V 20%	CAPACITOR CERAMIC SMD 0201 10V X5R 100 nF	Murata Electronics	GRM033R61A104ME15D
6	10	C907 C908 C909 C910 C911 C912 C913 C914 C915 C916	3pF 0201 25V 10%	CAPACITOR CERAMIC SMD 0201 25V COG 3pF	Murata Electronics	GRM0335C1E3R0CA01D
7	1	C917	10uF 0603 (1608 Metric) 10V 20%	Tantalum Capacitors - Solid SMD 10V 10uF 20%	Vishay	TR8M106M0102T2000
8	2	C920 C925	4.7uF 0201 6.3V 20%	CAPACITOR CERAMIC SMD 0201 6.3V X5R 4.7 uF	Murata Electronics	GRM035R60J475ME15D
9	2	C923 C930	5.3pF 0402 (1005 Metric) 50V 0.1pF	CAPACITOR CERAMIC SMD 0402 5.3pF 50V COG	Murata Electronics	GCQ1555C1H5R3BB01D

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
10	1	C932	47pF 0201 25V 5%	CAPACITOR CERAMIC SMD 0201 25V COG 47 pF	Murata Electronics	GRM0335C1E470JA01J
11	3	C933 C934 C935	33pF 0201 50V 5%	CAPACITOR CERAMIC SMD 0201 50V COG 33 pF	Murata Electronics	GRM0335C1H330JA01D
12	1	C937	47pF 0201 25V 5%	CAPACITOR CERAMIC SMD 0201 25V X5R 47 pF	Murata Electronics	GRM0335C1E470JA01J
13	1	C938	470nF 0402 (1005 Metric) 10V 10%	CAP CER 0.47UF 10% 10V X5R 0402	Yageo	CC0402KRX5R6BB474
14	1	C939	10pF 0402 (1005 Metric) 50V 5%	CAP CER 10pF 0.25pF 50V COG 0402	Kemet	C0402C100J5GACTU
15	3	C941 C943 C946	1nF 0201 50V 10%	CAPACITOR CERAMIC SMD 0201 50V X7R 1 nF	Murata Electronics	GRM033R71H102KA12D
16	1	C942	2.2pF 0402 (1005 Metric) 50V 0.05pF	CAP CER 2.2pF 0.05pF% 50V COG 0402	Murata Electronics	GJM1555C1H2R2WB01D
17	1	C949	1.5pF 0402 (1005 Metric) 50V 0.05pF	CAP CER 1.5pF 0.05pF% 50V COG 0402	Murata Electronics	GJM1555C1H1R5WB01D
18	5	C944 C945 C953 C954 C961	33pF 0402 (1005 Metric) 50V 1%	CAPACITOR CERAMIC SMD 0402 33pF 1% 50V COG	Murata Electronics	GJM1555C1H330FB01D
19	1	C947	6.2pF 0402 (1005 Metric) 50V 0.05pF	CAP CER 6.2pF 0.05pF 50V COG 0402	Murata Electronics	GJM1555C1H6R2WB01D
20	1	C948	4.3pF 0402 (1005 Metric) 50V 0.05pF	CAP CER 4.3pF 0.05pF 50V COG 0402	Murata Electronics	GJM1555C1H4R3WB01D
21	1	C950	47nF 0201 16V 10%	CAPACITOR CERAMIC SMD 0201 16V X5R 47 nF	Murata Electronics	GRM033R61C473KE84D
22	1	C951	68pF 0201 50V 5%	CAPACITOR CERAMIC SMD 0201 50V COG 68 pF	Murata Electronics	GRM0335C1H680JA01D
23	2	C952 C966	2.7pF 0402 (1005 Metric) 50V 0.1pF	CAP CER 2.7pF 0.1pF% 50V COG 0402	Yageo	CC0402BRNPO9BN2R7
24	1	C955	5.6pF 0402 (1005 Metric) 50V 0.25pF	CAP CER 5.6pF 0.25pF% 50V COG 0402	Murata Electronics	GRM1555C1H5R6BA01D
25	3	C956 C962 C964	3.3pF 0402 (1005 Metric) 50V 0.05pF	CAP CER 3.3pF 0.05pF% 50V COG 0402	Murata Electronics	GJM1555C1H3R3WB01D

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
26	1	C957	1.3pF 0402 (1005 Metric) 50V 0.05pF	CAP CER 1.3pF 0.05pF% 50V COG 0402	Murata Electronics	GJM1555C1H1R3WB01D
27	1	C963	3.6pF 0402 (1005 Metric) 50V 0.05pF	CAP CER 3.6pF 0.05pF 50V COG 0402	Murata Electronics	GJM1555C1H3R6WB01D
28	1	C965	1pF 0402 (1005 Metric) 50V 0.1pF	CAP CER 1pF 0.1pF% 50V COG 0402 (not mounted)	AVX Corporation	04025A1R0BAT2A
29	4	CL1 CL2 CL3 CL4	Clip-0951-46R	RFI SHIELD CLIP COMPACT TIN SMD	Harwin Inc.	S0951-46R
30	2	D900 D901	BAT30F4 0201 (0603 Metric) 300mA ST0201	30 V, 300 mA CSP general purpose small signal Schottky diode	ST	BAT30F4
31	1	D902	Led_RGB 0404 (1010 Metric) 5mA Red, 5mA Green, 5mA Blue	WL-SFCC SMT FULL-COLOR CHIP LED	Würth Elektronik	150044M155260
32	30	J900 J901 J902 J903 J904 J905 J906 J907 J908 J909 J910 J911 J912 J913 J914 J915 J916 J917 J918 J919 J920 J921 J922 J923 J924 J925 J926 J927 J928 J929	0 0402	TIN DROP JUMPER 0402 (not mounted)	-	-
33	2	J930 J931	CON 22 Header	CONN HEADER SMD 22POS 1.27MM (not mounted)	Samtec Inc.	FTSH-111-01-L-DV-K-P-TR
34	2	J932 J933	NX3L1T3157GM 6-XFDFN	IC SWITCH SPDT 6XSON	NXP USA Inc.	NX3L1T3157GMZ
35	1	J935	CON_SMA_Wurth_60312202114508	SMA PCB END LAUNCH JACK ROUND PO	Würth Elektronik	60312202114508
36	1	J936	UFL Wurth_636101111001 U.FL-R-SMT-1	WR-UMRF_PCB RECEPTACLE_SMT_3 PAD (not mounted)	Würth Elektronik	636101111001
37	1	J937	0 R 0603 1/10W 1%	RES SMD 1% 1/10W 0603 0 OHM	Vishay	CRCW06030000Z0EB
38	1	L900	2.2uH 1.2A 0806 (2016 Metric) 20%	FIXED IND 2.2UH 1.2A 110 MOHM	Würth Elektronik	74479776222
39	1	L901	2.2uH 1.2A 0806 (2016 Metric) 20%	FIXED IND 2.2UH 1.2A 110 MOHM	Würth Elektronik	74479776222

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
40	1	L902	600Ohm@100 MHz 0603 (16085 Metric) 300mA	INDUCTOR SMD 0603 600 OHM 100MHz	Chilisin Electronics	BBBK00160808601Y00
41	1	L903	15uH 0603 (16085 Metric) 250mA	INDUCTOR SMD 0603 15uH 250mA	TDK Corporation	MLZ1608N150LT000
42	1	L904	1kOhm 100MHz 0402 (1005 Metric) 250mA	INDUCTOR SMD 0402	Murata Electronics	BLM15HG102SN1D
43	2	L905 L912	3.3nH 0402 (1005 Metric) 2A 0.1nH	INDUCTOR SMD 0402 3.3nH	Murata Electronics	LQW15AN3N3B80D
44	2	L907 L908	47nH 0402 (1005 Metric) 210mA	INDUCTOR SMD 0402 47nH	Murata Electronics	LQW15AN47NJ00D
45	1	L909	3nH 0402 (1005 Metric) 1.35A	INDUCTOR SMD 0402 3nH	Murata Electronics	LQW15AN3N0C80D
46	3	L906 L910 L913	8.7nH 0402 (1005 Metric) 1.42A 2%	INDUCTOR SMD 0402 8.7nH	Murata Electronics	LQW15AN8N7G80D
47	1	L911	2.5nH 0402 (1005 Metric) 1A	INDUCTOR SMD 0402 2.5nH	Murata Electronics	LQW15AN2N5B80D
48	1	L914	11nH 0402 (1005 Metric) 500mA	INDUCTOR SMD 0402 11nH	Murata Electronics	LQW15AN11NG00D
49	1	Q1	VT6X1T2R VMT-6	Bipolar Transistors - BJT TR NPNX2 20V VCEO	ROHM Semiconductor	VT6X1T2R
50	1	Q2	2SCR522MT2L SOT-723 150mW	TRANS NPN 20V 0.2A VMT3	Rohm Semiconductor	2SCR522MT2L
51	4	R900 R909 R910 R911	100R 0201 1/20 1%	RES SMD 1% 1/20W 0201 100R 1/20W	PANASONIC	ERJ1GNF1000C
52	3	R901 R924 R930	1M 0201 1/20 1%	RES SMD 1% 1/20W 0201 1M 1/20W	Yageo	RC0201FR-071ML
53	3	R902 R903 R904	10k 0201 1/20 1%	RES SMD 1% 1/20W 0201 10K 1% 1/20W	VISHAY	CRCW020110K0FKED
54	31	R905 R906 R913 R914 R915 R916 SB900 SB901 SB902 SB904 SB905 SB906 SB907 SB908 SB909 SB910 SB911 SB912 SB913 SB918 SB922 SB923 SB924 SB925 SB926 SB927 SB928 SB929 SB931 SB940 SB941	0R 0201 1/20 1%	RES SMD 1% 1/20W 0201 0R 1/20W	Stackpole Electronics	RMCF0201ZT0R00

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
55	1	R908	220R 0201 1/20 1%	RES SMD 1% 1/20W 0201 220R 1/20W	Yageo	RC0201FR-07220RL
56	1	R917	30k 0201 1/20 1%	RES SMD 1% 1/20W 0201 30K 1% 1/20W	Yageo	RC0201FR-0730KL
57	1	R918	120k 0201 1/20 1%	RES SMD 1% 1/20W 0201 120K 1% 1/20W	Panasonic Electronic	ERJ-1GNF1203C
58	1	R919	51k 0201 1/20 1%	RES SMD 1% 1/20W 0201 51K 1% 1/20W	MULTICOMP	ERJ-MCRE000181
59	1	R920	20R 0201 1/20 1%	RES SMD 5% 1/20W 0201 20R 5% 1/20W	Panasonic Electronic	ERJ-1GNJ200C
60	1	R921	0R 0402 (1005 Metric) 1/16W 1%	CHIP RESISTOR SMD 5% 1/16W 0402	Yageo	RC0402JR-070RL
61	1	R922	33R 0201 1/20 1%	RES SMD 1% 1/20W 0201 33R 5% 1/20W	Panasonic Electronics	ERJ-1GNJ330C
62	2	R925 R926	100k 0201 1/20 1%	RES SMD 1% 1/20W 0201	MULTICOMP	MCRE000188
63	1	R923	1M 0201 1/20 1%	RES SMD 1% 1/20W 0201 1M 1/20W (not mounted)	Yageo	RC0201FR-071ML
64	1	R927	82R 0201 1/20 5%	RES SMD 1% 1/20W 0201 82R 5% 1/20W	Panasonic Electronic	ERJ-1GNJ820C
65	7	SB903 SB915 SB916 SB920 SB921 SB930 SB932	0R 0201 1/20 1%	RES SMD 1% 1/20W 0201 0R 1/20W (not mounted)	Stackpole Electronics	RMCF0201ZT0R00
66	1	SH1	Shield MS190-10S	19 X 13.9 X 2MM EMI/RF SHIELD	Masach Tech Ltd.	MS190-10S
67	1	TP900	TP	Test point (not mounted)	-	-
68	1	TP901	TP	Test point (not mounted)	-	-
69	66	TPB900 TPB901 TPB902 TPB903 TPB904 TPB905 TPB906 TPB907 TPB908 TPB909 TPB910 TPB911 TPB912 TPB913 TPB914 TPB915 TPB916	TPB	Test point (not mounted)	-	-

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
		TPB917 TPB918 TPB919 TPB920 TPB921 TPB922 TPB923 TPB924 TPB925 TPB926 TPB927 TPB928 TPB929 TPB930 TPB931 TPB932 TPB933 TPB934 TPB935 TPB936 TPB937 TPB938 TPB939 TPB940 TPB941 TPB942 TPB943 TPB944 TPB945 TPB946 TPB947 TPB948 TPB949 TPB950 TPB951 TPB952 TPB953 TPB954 TPB955 TPB956 TPB957 TPB958 TPB959 TPB960 TPB961 TPB962 TPB963 TPB964 TPB965			
70	56	TPE130 TPE131 TPE132 TPE133 TPE134 TPE148 TPE149 TPE150 TPE151 TPE152 TPE900 TPE901 TPE902 TPE903 TPE904 TPE905 TPE906 TPE907 TPE908	TPE	Test point (not mounted)	-	-

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
		TPE909 TPE910 TPE911 TPE912 TPE913 TPE914 TPE915 TPE916 TPE917 TPE918 TPE919 TPE920 TPE921 TPE922 TPE923 TPE924 TPE925 TPE926 TPE927 TPE928 TPE930 TPE932 TPE934 TPE936 TPE943 TPE944 TPE945 TPE946 TPE947 TPE948 TPE949 TPE950 TPE951 TPE952 TPE953 TPE954 TPE955				
71	2	FB1 FB2	470Ohms@100 MHz 0201 (0603 Metric)	FERRITE BEAD 470 OHM 0201 1LN	Murata Electronics	BLM03BD471SN1D
72	1	U900	ST1PS02CQTR MLPQ/QFN 1.7x2.0x0.55 12L P0.4	400 mA nano-quiescent synchronous step-down converter with digital voltage selection, Power Good and AUX switch	ST	ST1PS02CQTR
73	1	U901	STSAFA110DF SPL02 UFDFPN 8 2x3x0.6	Authentication, state-of-the-art security for peripherals and IoT devices	ST	STSAFA110DFSPL02
74	1	U902	STM32WB5MM GH6TR SIP LGA 86 7.3x11x1.342 mm	Ultra-low-power Module - Dual core Arm Cortex-M4 MCU 64 MHz, Cortex-M0+ 32 MHz with 1 Mbyte of Flash memory, Bluetooth LE 5.2, 802.15.4, Zigbee, Thread,	ST	STM32WB5MMGH6TR

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
				USB, LCD, AES-256		
75	1	U903	STM32WL55JCI6 UFBGA 73 5x5x0.6 P 0.5 mm	Sub-GHz Wireless Microcontrollers . Dual-core Arm Cortex-M4/M0+ @48 MHz with 256 Kbytes of Flash memory, 64 Kbytes of SRAM	ST	STM32WL55JCI6
76	1	U904	BGS13SN8 8-XFQFN	IC RF SWITCH SP3T TSNP8-1	Infineon Technologies	BGS13SN8E6327XTSA1
77	1	Y900	32.768kHz 2-SMD, No Lead	CRYSTAL 32.768KHZ 6PF SMD	NDK America, Inc.	NX2012SA-32.768KHZ-EXS00A-MU00527
78	1	Y901	32MHz 4-SMD, No Lead	XTAL OSC VCTCXO 32.0000MHZ SMD	NDK America, Inc.	NT2016SA-32M-END4263A

Table 8. STDES-CBMLoRaBLE: flexible cable no. 1 bill of materials

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
1	1	J2	CON34-Header	CONN HDR 34POS SMD GOLD	Panasonic Electric Works	AXF6G3412A
2	2	J1 J3	CON34-Socket	CONN SOCKET 34POS SMD GOLD	Panasonic Electric Works	AXF5G3412A

Table 9. STDES-CBMLoRaBLE: flexible cable no. 2 bill of materials

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
1	1	J2	CON34-Header	CONN HDR 34POS SMD GOLD	Panasonic Electric Works	AXF6G3412A
2	1	J1	CON34-Socket	CONN SOCKET 34POS SMD GOLD	Panasonic Electric Works	AXF5G3412A

7 Conclusions

The proposed platform has been tested under all the conditions previously described, using all possible power sources and different assembly scenarios.

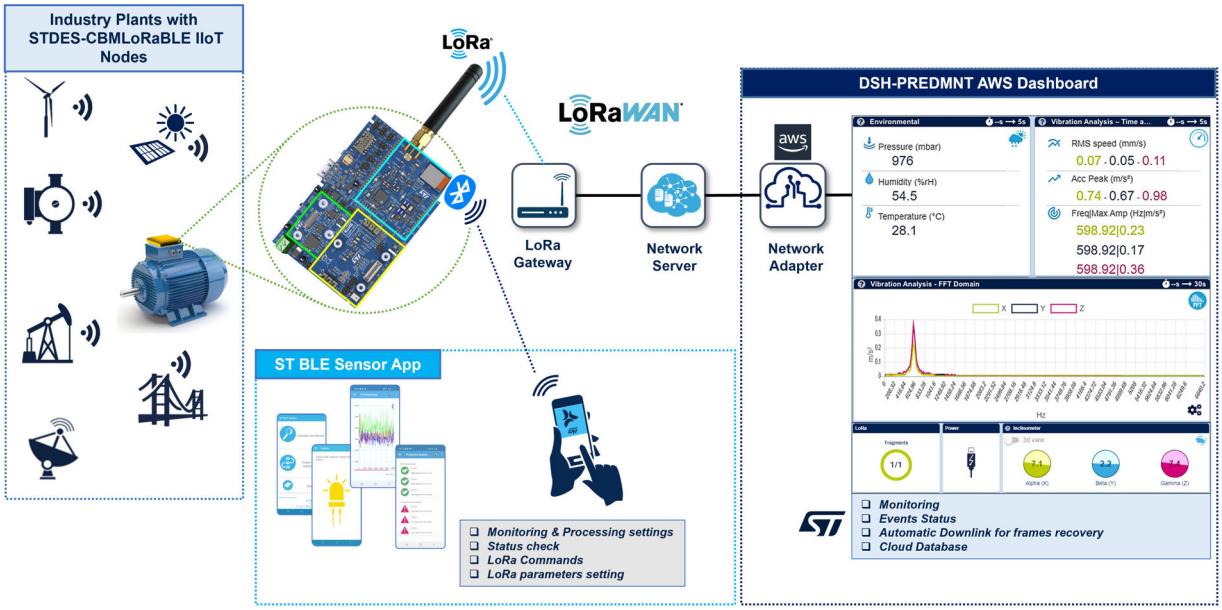
The short-range connectivity (BLE) is particularly suitable to monitor nearby conditions, when the user wants to change the processing settings, including the firmware upgrade.

Long-range connectivity (LoRa) is well supported by DSH-PREDMNT, where the inclinometer processing data, event history, and data storage are also available.

The hardware design with a modular approach allows developing other expansion boards for innovative applications, based on other MEMS or analog sensors.

The figure below shows an overview of the final application.

Figure 46. Final application overview



The STDES-CBMLoRaBLE represents a complete solution proposal for IIoT nodes in industrial fields that operate in remote areas, with harsh environmental conditions and low connection capability, such as oil and gas, mining, wind and photovoltaic farms, and large infrastructure monitoring.

It contains the right key elements, such as smart sensor nodes, with embedded processing, and is able to send the data results on the network in a secure way. The network architectures used are based on complex monitoring systems with multiple nodes and gateways that often present cabling issues over short and long ranges. Wireless technology could be a good alternative, flexible and scalable to extend the coverage area, without limits for distances, with a long battery lifetime, and a low bitrate.

Appendix A Reference design warnings, restrictions and disclaimer

Important: *The reference design is not a complete product. It is intended exclusively for evaluation in laboratory/ development environments by technically qualified electronics experts who are familiar with the dangers and application risks associated with handling electrical/mechanical components, systems and subsystems.*

Danger: *Exceeding the specified reference design ratings (including but not limited to input and output voltage, current, power, and environmental ranges) may cause property damage, personal injury or death. If there are questions concerning these ratings, contact an STMicroelectronics field representative prior to connecting interface electronics, including input power and intended loads. Any loads applied outside of the specified output range may result in unintended and/or inaccurate operation and/or possible permanent damage to the reference design and/or interface electronics. During normal operation, some circuit components may reach very high temperatures. These components include but are not limited to linear regulators, switching transistors, pass transistors, and current sense resistors which can be identified in the reference design schematic diagrams.*

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Revision history

Table 10. **Document revision history**

Date	Revision	Changes
03-Nov-2022	1	Initial release.
09-Nov-2022	2	Updated Section 6 Bill of materials.

Contents

List of tables

List of figures